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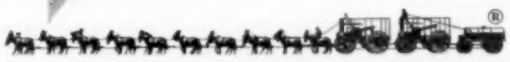

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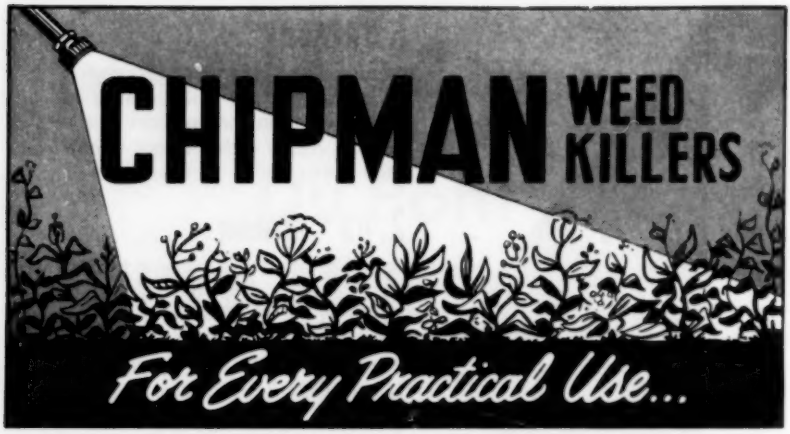

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Weeds

JOURNAL OF THE WEED SOCIETY OF AMERICA

VOLUME 6 JANUARY 1958 NUMBER 1

Canada Thistle (*Cirsium arvense* Scop.) Control with Cultivation, Cropping, and Chemical Sprays[1]

JESSE M. HODGSON[2]

CANADA thistle (*Cirsium arvense* Scop.), a widely distributed weed in northern United States, according to Dewey (3), was introduced from Europe in 1777. In 1901 Blankenship (1) reported it to be rare in Montana having been identified in only five locations. However, a report issued in 1956 by Heikes (6), showed an estimated 625,000 infested acres in Montana. Another report of a survey of the four northwestern states including Montana, Idaho, Oregon, and Washington estimated their total of Canada thistle at more than 1.5 million acres infested (4). This was considerably more than any other weed of this region. Control measures for this weed are, therefore, of primary importance.

Although methods of controlling Canada thistle have been developed and recommended, it is still spreading and infesting more land each year as indicated in the above reports. The three different ways generally employed for control of Canada thistle involve: cultural practices, cropping practices, or chemical treatments. Tingey (11) and Seely (10), reported 100 percent kill of Canada thistle in one season by shallow cultivation. Cox in 1913 (2), also described a cultivation procedure by which Canada thistle was eliminated from cropland. Gilchrist (5) reported that repeated mowing in pastures for 2 years "will practically remove thistles". Control of Canada thistle by mowing was also found to be effective by Welton et al. (12). Robbins et al. (9) discussed the value of competitive crops to control Canada thistle and reported alfalfa to be especially effective.

The use of soil sterilant chemicals with the resultant loss of crop production was found to be quite effective in control and eradication of Canada thistle (11). The selective type herbicide, 2,4–D was also found to give control of Canada thistle when applications were repeated (8). The discovery of 2,4–D has made possible a selective

[1]Cooperative investigations in weed control by the Crops Research Division, A.R.S., U.S.D.A., and the Montana Agricultural Experiment Station, Bozeman, Montana: and Region 6 of the Bureau of Reclamation, U.S.D.I., Montana Agricultural Experiment Station Paper No. 412, Journal Series.

[2]Research Agronomist, Crops Research Division, A.R.S., U.S.D.A.

chemical treatment for control of Canada thistle as a supplement to cropping and cultivation methods.

As indicated by the work cited above, the evaluation of cropping and cultural practices and of chemical treatments for control of Canada thistle has been quite extensive. However, cropping and cultural practices were not included in the same experiment with 2,4–D sprays as separate control practices and as combined treatments in control of Canada thistle. Certain combination treatments of cropping, cultviation and 2,4–D sprays were found to be more effective and less costly in control of whitetop (7) than treatments involving any one of the methods used alone. The study reported herein was designed to determine the relative effectiveness of similar combination methods in controlling Canada thistle.

EXPERIMENTAL PROCEDURE

In the spring of 1953, an established infestation of Canada thistle in a newly seeded pasture located near Bozeman, Montana on Huffine silt loam was selected for the experimental area. The average annual rainfall of this area is 18 inches. Additional water was applied as needed each year by sprinkler irrigation. Sixteen treatments involving wheat, forage grasses, alfalfa, corn and pea crops, and cultivation and chemical spray were used. These treatments were randomized and replicated four times on plots 30 feet wide and 80 feet long. All treatments were scheduled to be conducted over a 4-year period. Roadways were established between replications to facilitate the farming operations.

All farming operations, such as plowing, seeding, cultivation and spraying were done with regular tractor-mounted field equipment. A duckfoot cultivator with rigid shanks and 16-inch sweeps was used in the continuous cultivation plots. Certain treatments received nitrogen fertilizer at a rate of 50 pounds of nitrogen per acre applied before seedbed preparation.

The 16 different treatments are listed below by letter designation. Treatment B was originally planned to be sprayed with 2,4–D in the spring and fall, however, weed regrowth did not appear as expected in the period between harvest and fall plowing. Treatments A and B are, therefore, identical and the data on these plots were combined. Each treatment was repeated each year unless otherwise specified as to the variation in treatment applied each year. All plots were plowed in the early spring the first year and immediately after grain harvest each year thereafter.

A and B. Spring wheat, nitrogen fertilizer and 2,4–D spray each year:

1. Nitrogen fertilizer applied in spring just prior to seedbed preparation.
2. Thatcher wheat seeded.
3. Sprayed with ¾ pound of ester formulation[3] of 2,4–D per acre; very early bud stage of Canada thistle.

[3]Propylene glycol butyl ether ester unless otherwise indicated.

4. Plowed immediately after harvest.

C. Spring wheat and nitrogen fertilizer each year, no 2,4–D:
   1. Nitrogen fertilizer applied in spring just prior to seedbed preparation.
   2. Thatcher wheat seeded.
   3. Plowed immediately after harvest.

D. Spring wheat, no fertilizer, but sprayed with 2,4–D each year:
   1. Seedbed prepared.
   2. Thatcher spring wheat seeded.
   3. Sprayed with ¾ pound of 2,4–D per acre; very early bud stage of Canada thistle.
   4. Plowed immediately after harvest.

E. Spring wheat cropping only each year:
   1. Seedbed prepared.
   2. Thatcher spring wheat seeded.
   3. Plowed immediately after harvest.

F. Alfalfa and mowing, 4 years:
   1. Seedbed prepared.
   2. Ranger alfalfa seeded without nurse crop.
   3. Mowed twice for hay each year.

G. Seeded pasture, sprayed with 2,4–D, 4 years:
   1. Mixed pasture of orchard grass and smooth brome and ladino clover.
   2. Sprayed with ¾ pound of 2,4–D per acre 8 weeks after emergence of grass first year.
   3. Sprayed with ¾ pound of 2,4–D per acre at early bud stage of Canada Thistle each following year.
   4. Pasture clipped 2 to 3 times each year.

N. Grass in rows for seed, row cultivated, and sprayed with 2,4–D, 4 years:
   1. Orchard grass and smooth bromegrass seeded in rows without nurse crop.
   2. Sprayed with ¾ pound of 2,4–D per acre 8 weeks after emergence of grass seedlings first year and at early bud stage of Canada thistle each year thereafter.
   3. Cultivation between rows once in early spring each year.
   4. Grass seed harvested with binder.

H. Cultivation, and alternate spring wheat and 2,4–D:
   1. Cultivated with duckfoot sweeps 3- to 4-inch depth every 21 days for one season.
   2. Spring wheat seeded second season.
   3. Applied 2,4–D, ¾ pound per acre, at early bud stage of Canada thistle.
   4. Plowed immediately after harvest.
   5. Step one repeated in 3rd season and steps 2 and 3 in the 4th season.

M. Cultivation and 2,4–D and alternate winter wheat and 2,4–D:
   1. Cultivated every 21 days until July 15, 2,4–D applied 6 weeks later on Canada thistle regrowth.
   2. Seedbed prepared and winter wheat planted September 15.

3. Applied ¾ pound of 2,4–D per acre in wheat following spring at early bud stage of Canada thistle.
4. Same procedure next 2 years except no 2,4–D in fallow year.

K. Rotation: Wheat and 2,4–D and alfalfa and mowing:
1. 1st year: Spring wheat seeded, sprayed with 2,4–D at ¾ pound per acre at early bud stage of Canada thistle, fall plowed.
2. 2nd year: Alfalfa seeded without nurse crop.
3. 3rd and 4th years: Alfalfa mowed twice each year for hay.

L. Rotation: Seeded pasture and 2,4–D and wheat and 2,4–D:
1. 1st year: Pasture seeded and sprayed with 2,4–D 8 weeks after emergence of grass seedlings.
2. 2nd and 3rd years: Pasture sprayed with 2,4–D at early bud stage of Canada thistle and clipped.
3. 4th year: Plowed, fertilized with nitrogen, planted wheat and sprayed with 2,4–D.

O. Peas and MCPA spray each year:
1. Seedbed prepared and Cascade canning peas planted.
2. MCPA, amine formulation,[4] applied at ¼ and ½ lb/A when peas were 4- to 5-inches high.
3. Peas harvested for seed.

P. Row cropping, inter-row cultivation, and 2,4–D:
1. 1st year: Potatoes planted, cultivated twice between rows, 2,4–D applied at 1 lb/A 2 weeks before harvest.
2. 2nd, 3rd, and 4th years: Silage corn planted after one spring cultivation, 2,4–D applied at 1 lb/A amine formulations[5] when corn was 8- to 12-inches tall, corn harvested as silage and ground fall-plowed.

Q. 2,4–D spray only, 4 years:
1. Applied 2 pounds of 2,4–D ester formulation per acre each year at early bud stage of Canada thistle.

R. Control, 4 years:
1. No treatment.

The Canada thistle population on each plot was sampled in June each year by counting the number of Canada thistle shoots on 10 permanent 3-foot square quadrats. The sample was taken the first year before spraying or cultivation was begun. Follow-up counts were made each year at approximately the same time. The quadrat counts were made at the same established locations each year by the use of a removable line transect and 3-foot square quadrat. Permanent marks were made just outside the plot area at a point opposite the center of each plot. It was then possible to attach the removable wire to the permanent marks each year and stretch it across the plots lengthwise to relocate the established points. The 3-foot square quadrat was then placed in turn at 10 points which

[4]Diethanolamine
[5]Triethanolamine

were painted on the wire transect and the Canada thistle shoots at each location counted.

Wheat yields were sampled by taking 6 rod-row samples at random through the center of each plot the first 2 years and by sampling the same areas as the Canada thistle count the 3rd and 4th years. Forage crop and pea yields were sampled by taking one mower-swath width 33 feet long and 6 feet wide in the center of the plots. The forage samples were oven-dried.

The 2,4–D spraying was done with a tractor-mounted sprayer and 20-foot boom. The sprayer boom was made in two ten-foot sections. This made it possible to spray each 30-foot wide plot in one and a half swaths with no tractor tracks being made in the center of the plot or sampling area. The spray treatments were applied each year in 20 gallons of water per acre after Canada thistle counts were made.

RESULTS AND DISCUSSION

The data on Canada thistle survival presented in Tables 1, 2, 3, and 4 were obtained each year in June. They actually represent the effect of the previous years treatment in each case. For this reason the 1956 figures on number of Canada thistle shoots represent the cumulative effect of only 3 seasons of treatments, whereas, crop yields represent yields for the year under which they are tabulated.

The results of this experiment show the advantage of combining cropping, cultivation and chemical spraying for control of Canada thistle. The stand of Canada thistle was reduced by all treatments which involved 2,4–D spraying. However, complete eradication was accomplished by only two treatments during the 4 years of the experiment, to date. These treatments involved continuous delayed cultivation, alternate years with wheat sprayed with 2,4–D (Treatment H), and row cropping with potatoes and silage corn, and 2,4–D spray (Treatment P).

Cropping with alfalfa and mowing (Treatment F) as a method of controlling Canada thistle was found to be a very effective control measure. Cultivation was also very effective in eliminating Canada thistle when performed every 21 days for one growing season (Treat-

Table 1. The effect of spring wheat, nitrogen fertilizer, and 2,4–D spray on the control of Canada thistle, Bozeman, Montana.

Crop, and/or cultural or chemical treatment	Canada thistle shoots—pct. original stand				Yield of wheat—bu/A					Net increase above treatment E in 4 years–bu/A.[a]
	1953	1954	1955	1956	1953	1954	1955	1956	Ave.	
A & B. Spring wheat, nitrogen fertilizer, and 2,4-D spray	100	9	3	1	55	59	51	68	58.3	69
C. Spring wheat, nitrogen fertilizer	100	156	310	312	63	48	29	30	42.5	10
D. Spring wheat, 2,4-D spray	100	14	3	1	54	65	48	44	52.7	63
E. Spring wheat, check	100	119	147	157	49	47	28	20	36.0	0
Q. Sprayed with 2,4-D only, each year	100	29	49	39	—	—	—	—	—	

[a]The number of bushels of wheat equivalent to the cost of extra treatments with 2,4-D and/or nitrogen were deducted. Price of wheat assumed to be $2.00 per bushel.

ment H). 2,4–D spray when used alone (Treatment Q) proved to be less effective than either cultivation or cropping treatment (Treatment F).

Effect of spring wheat combined with spraying, nitrogen, fertilization, and cultivation.

The selective treatment of Canada thistle in spring wheat with 2,4–D gave very effective control. As shown in Table 1, the stand of Canada thistle was reduced more than 99 percent on spring wheat plots sprayed with ¾ pound of 2,4–D per acre each year for both fertilized and unfertilized treatments. The application of nitrogen fertilizer apparently had no effect on kill of Canada thistle in these plots. The soil in the plot area was in a good state of fertility at the beginning of the experiment as shown by the yields of wheat. The wheat yields for 1957, however, show the depletion that occurred and a definite response was observed from nitrogen fertilizer on both 2,4–D sprayed and the non-sprayed wheat plots.

The Canada thistle in this experiment was quite susceptible to treatment with 2,4–D as evidenced by the large reduction in numbers of shoots in most plots after the first year of treatment. An average of nearly 90 percent fewer shoots was recorded on the 2,4–D sprayed wheat plots in 1954 than in 1953 when the experiment was begun. These treatments reduced the remaining thistle shoots to 3 percent in 1955 and to 1 percent in 1956. While the reduction of Canada thistle shoots after the first year was quite large they were reduced very little in the next 2 years.

The stand of Canada thistle has increased each year in the spring wheat plots that were not sprayed with 2,4–D. The number of shoots more than doubled in 3 years on the plots that received nitrogen fertilizer while the increase was only 57 percent on the spring wheat plots not fertilized. Apparently this increase of Canada thistle growth was a response to the nitrogen fertilizer.

These results indicate that spring wheat as a cropping method alone for control of Canada thistle is ineffective and actually allows further spread of Canada thistle rather thn giving any control of the weed.

Shown in Table 2 are the yields for the three wheat crops affected by each of the treatments. The yields indicate a high level of fertility of the plot area at the beginning of the experiment. However, plots not receiving nitrogen decreased in yield each year. The plots not sprayed with 2,4–D also decreased in yield each year as the thistle infestation increased.

Spraying with 2,4–D resulted in the greatest increase in yield per unit cost of treatment, however, the combination of nitrogen fertilizer and 2,4–D spray gave the greatest net increase in yield.

Effect of forage crops, mowing and 2,4–D

As shown in Table 3, alfalfa was a highly effective crop, when mowed twice each year, in eliminating Canada thistle in this experiment. After 3 years, the number of Canada thistle shoots remaining

Table 2. The effect of wheat cropping, cultivation, and 2,4–D spray treatments on control of Canada thistle and crop returns.

Crop, and/or cultural or chemical treatment	Survival of Canada thistle—pct			Yields—bu/A			3 year net income per acre[a]
	1954	1955	1956	1954	1955	1956	
E. Spring wheat	119	147	157	47	28	20	$ 55.00
D. Spring wheat, sprayed with 2,4-D	14	3	1	65	48	44	173.00
C. Spring wheat, nitrogen fertilized	156	310	312	48	29	30	55.00
A & B. Spring wheat, nitrogen fertilized and sprayed with 2,4-D	9	3	1	59	51	68	191.00
H. 1st year, cultivated fallow; 2nd year, wheat sprayed with 2,4-D; 3rd year, cultivated fallow	.3	.7	0	55	0	57	107.00
Q. 2,4-D spray only	29	49	39	—	—	—	

[a]For 3-year period after deducting annual costs as follows: wheat production $45.00 per acre; 2,4-D spray $2.00 per acre; nitrogen fertilizer $8.00 per acre; price of wheat assumed to be $2.00 per bushel.

was less than 1 percent of the original found on these plots and the alfalfa yields were about as normally expected for the area on land free from Canada thistle. The advantages of the growth habits of alfalfa over Canada thistle were observed in these treatments. Alfalfa emerged earlier in the spring, forming a highly competitive cover. It also recovered more quickly after mowing. It should be pointed out that mowing of Canada thistle has been found to be an important control practice in connection with the alfalfa crops since alfalfa plots that were not mowed[6] did not give the control of Canada thistle that was obtained by mowing.

Table 3. The effect of forage crops, mowing and spraying with 2,4–D in control of Canada thistle.

Crops and/or cultural or spraying treatments	Canada thistle survival—percent original stand				Annual yield—tons per acre			
	1953	1954	1955	1956	1953	1954	1955	1956
	Percent original stand				Tons per acre			
F. Alfalfa seeded and mowed once 1st year, mowed twice each year following	100	14	5	1	0.8	5.4	3.5	4.1
G. Pasture grass seeded and sprayed with 2,4-D, 8 weeks after emergence. After 1st year sprayed each year and mowed. Nitrogen fertilizer applied in 1956	100	13	3	.1	0.8	2.2	1.8	2.5
N. Grass seeded in rows for seed production, sprayed 8 weeks after emergence. After 1st year sprayed and harvested for seed. One cultivation between the rows each year for first 3 years	100	19	2	4	0	265[a]	225[a]	175[a]

[a]Pounds per acre.

Plots of seeded pasture that were sprayed with 2,4–D and mowed two or three times also gave almost complete eradication of Canada thistle. It is interesting to speculate just what part the mowing and 2,4–D contributed in this result. However, separate plots of each

[6]Unpublished data: J. M. Hodgson, Crops Research Division, A.R.S. Bozeman, Montana.

were not possible. The seeded grasses which were sprayed with 2,4–D and harvested as seed, were slightly less effective in eliminating Canada thistle. This latter treatment was not mowed, however, one intertillage operation in the grass rows was made each year.

All of the forage crop treatments proved highly effective in control of Canada thistle in this experiment and they should be considered as practical methods for control of this weed.

Effect of intensive cultivation, 2,4–D spraying alone and combined with wheat cropping to control Canada thistle.

The results given in Table 4 show the effectiveness of cultivation in controlling Canada thistle. Treatment H which consisted of plowing early in May, 1953 had 6 duckfoot cultivations at 21-day intervals during that season, which caused a reduction of over 99 percent in thistle shoots as determined in June, 1954. One season of cultivation was more effective than a half season of cultivation followed by 2,4–D treatment in late August on thistle regrowth as shown in Treatment M, Table 4, results for the first year after treatment.

Table 4. The effect of combining intensive cultivation wheat cropping and 2,4–D spraying without cropping and/or 2,4–D.

Crop, and/or cultural spraying treatment	Canada thistle survival—per cent original stand				Annual yield—bu/A			
	1953	1954	1955	1956	1953	1954	1955	1956
H. Alternate cultivation and spring wheat *1953:* Duckfoot cultivation every 21 days. *1954:* Spring wheat sprayed with 2,4-D. *1955:* Same as 1953. *1956:* Same as 1954.	100	.3	.7	0	—	55	—	57
M. Alternate cultivation 2,4-D and spring wheat *1953:* Duckfoot cultivate at 21-day interval until July 15. Sprayed with 2,4-D on Aug. 21. Winter wheat planted Sept. 15. *1954:* Winter wheat sprayed with 2,4-D. *1955:* Duckfoot cultivated every 21 days. *1956:* Winter wheat, no 2,4-D.	100	14	8	12	—	61	—	46
Q. Sprayed with 2,4-D each year, no other treatment.	100	28	49	39	—	—	—	—
R. Control—no cropping, cultivation or spray treatment. Was mowed once 1955.	100	136	189	142	—	—	—	—

The 2,4–D treatment only, Treatment Q, was considerably less effective in control of Canada thistle than cultivation as determined in 1954 and after the 3 years of 2,4–D treatment was much less effective than cultivation and alternate wheat cropping. In fact, spraying with 2,4–D only, without wheat or pasture grass, gave less control of Canada thistle as well as being unproductive of crop during the period. This can be noted by comparing Treatment Q and D, Table 1, and Treatment G, Table 3. The survival of thistle shoots in the third year after treatment was 39 percent for 2,4–D spraying as compared to 1 percent for 2,4–D spraying in spring wheat, and 0.1 percent for 2,4–D spraying in pasture, indicating a definite beneficial effect from the combined cropping and spraying combination.

Treatment R, Table 4, the control treatment was mowed once in late August, 1955. There was a definite decrease in Canada thistle shoots on these plots the following season as recorded in June, 1956. It had been assumed that such a late mowing which was done to limit seed blowing would have no practical effect on the Canada thistle.

Effect of forage and cereal crop rotations, silage corn, and peas with combined herbicide treatments on control of Canada thistle.

Spring wheat sprayed with 2,4–D was followed by alfalfa and mowing for 3 seasons in one rotation practise, Treatment K. Pasture grass was sprayed with 2,4–D each year for 3 seasons and wheat was sprayed with 2,4–D the 4th season in rotation, Treatment L. As is shown in Table 5, rotation L involving the 3 years of pasture grass has given somewhat better kill of Canada thistle. This was probably influenced by the partial recovery of Canada thistle during the year of establishing alfalfa. Both rotation treatments indicate that the continuous cropping or cropping and spraying treatments reported in Tables 1 and 2 can be combined into desirable rotations including grains and forage crops which will give effective control of Canada thistle.

Table 5. The effect of two crop rotations and continuous row crop and continuous peas combined with herbicide treatments on survival of Canada thistle.

Crop, and/or cultural spraying treatment	Canada thistle survival—percent original stand				Yields—bu/A or tons/A			
	1953	1954	1955	1956	1953	1954	1955	1956
K. Rotation:								
Year 1:Spring wheat sprayed with 2,4-D.					57.6			
Years 2, 3, and 4: Alfalfa and mowing	100	29	46	24		2.0	3.7	4.9
L. Rotation:								
Years 1, 2, and 3:Pasture grass sprayed with 2,4-D.					0.8	2.4	2.3	
Year 4: Spring wheat fertilized with nitrogen and sprayed with 2,4-D	100	17	6	5				48.1
O. Continuous peas:								
Sprayed with ¼ lb/A MCPA	100	41	52	118	71.0	62,7	11.3	40.1
Sprayed with ½ lb/A MCPA	100	22	27	39	64.1	56.4	13.5	44.1
P. Row crop:								
Year 1: Potatoes sprayed with 2,4-D just before harvest.					332			
Years 2, 3, and 4: Silage corn sprayed with 2,4-D. (these crops intertilled twice and tilled once before planting each year).	100	17	0	0		17.4	22.9	27.3

Also included in Table 5 are the results of treatments involving continuous pea cropping and continuous row cropping and spraying. Treatment O involved peas sprayed with MCPA at ¼ and ½ pounds per acre. The control of Canada thistle obtained with the lower rate of application consisted mainly in a stunting of shoots and prevention of flowering of most shoots. The higher rate was considerably more effective actually killing some of the shoots. There was a slight decrease in Canada thistle stand after 3 seasons

on plots treated with MCPA at ½ pound per acre and a slight increase on the plots treated with MCPA at ¼ pound per acre. The yield of peas was very low in the second crop year after the experiment was begun. This is attributed to late seeding of the peas and a heavy infestation of redroot pigweed and pigeon grass which were not controlled by the treatments with MCPA. One of the outstanding treatments in the experiment was Treatment P which actually gave eradication of Canada thistle on all four replications after 3 seasons. Undoubtedly the cultivation before planting the crop was beneficial in this treatment.

SUMMARY

Sixteen different combination and single treatments for the control of Canada thistle were tested during a 4-year period, 1953 to 1956 at Bozeman, Montana.

Combinations of cropping, cultivation, and chemical spraying treatments applied in successive years in this experiment were found to be effective and practical in control of Canada thistle.

The data presented show that 2,4–D is more effective in controlling Canada thistle when used with competitive crops such as wheat, pasture grass, or silage corn than when used without cropping. Combining 2,4–D spray with spring wheat production gave effective control of Canada thistle and resulted in a large increase in yield

Figure 1. Plot shown at left of picture is Treatment A, spring wheat fertilized with nitrogen and sprayed with 2,4–D. Plot at right is Treatment C, spring wheat fertilized with nitrogen but not sprayed.

of wheat during the 4 years of the experiment. Application of nitrogen fertilizer with spring wheat production caused growth of thistle to increase but also maintained the wheat production at a higher level. On 2,4–D sprayed plots, Canada thistle was about equally controlled whether nitrogen was applied or not.

Alfalfa mowed twice each year, and a seeded pasture mixture of grass and ladino clover sprayed with 2,4–D and mowed each year, reduced the stand of Canada thistle 99 percent or more in 3 years. Grass grown in rows for seed production and sprayed once each year with 2,4–D and cultivated once each year was nearly as effective.

One season of cultivation every 21 days eliminated 99 percent of the Canada thistle. This treatment combined in alternate years with 2,4–D sprayed spring wheat gave almost complete elimination of Canada thistle in 4 years.

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Factors Affecting Dormancy and Seedling Development in Wild Oats[1]

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GRAINS of wild oats (*Avena fatua* L.) may remain dormant in the soil for several years or even for decades. The reasons for this dormancy are not known, but various hypotheses have been advanced to explain it, such as that the hull acts as a barrier to oxygen (1,7), and that a toxic substance is present in the hull as in cultivated oats (5). The tests here reported were undertaken to further explore some aspects of the problem of dormancy in wild oats.

MATERIALS AND METHODS

Thirty-two lots of wild oat grains were collected from 21 locations in North Dakota, 8 in Minnesota, and 3 in Montana.[3] All of the 32 samples appeared to be *Avena fatua* L. var. *intermedia* (Lestibi) Lej. & Court., using characters suggested by Lindsay (9) and Malzew (10). Tests were made about 6 months from harvest, on all 32 lots, unless stated otherwise. Dark-colored grains comprised 35 to 95 per cent of the grains in each collection and averaged 67 per cent for the 32 lots (8). Grains with dark colored hulls and those with light colored hulls were selected from each lot, and were tested for germination by placing 100 or 200 grains of each on moist filter paper in Petri plates, 20 per plate.

Two hundred grains from each lot were submerged and shaken for 2 minutes in a 1 per cent solution of sodium hypochlorite, placed on acid potato-dextrose agar (PDA) in Petri plates, and incubated for about 10 days to allow fungi within the grain to grow out.

For additional tests on grain microflora, PDA was used for bacterial counts, acid PDA for yeasts and some fungi, and malt-salt agar for storage molds and some yeasts.

To investigate further the possibility that microflora on or within the hull or on or within the caryopsis may affect dormancy, grains were soaked overnight in tap water at room temperature, then spread out on moist newspaper. Germinated and nongerminated grains were counted after 48 hours of incubation. One hundred each of germinated and nongerminatd grains were selected. Each lot of 100 was treated separately, and placed in 500 ml of 0.2 per cent sterile agar solution and comminuted for 1½ minutes in a Waring Blendor. Five ml of the resulting suspension were added to 45 ml of 0.2 per cent sterile agar solution, shaken 100 times, then 1 ml portions were put in Petri plates. Agar cooled to 51° C was poured into

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[3]Seed lots were obtained through the efforts of Donald G. Fletcher, Rust Prevention Association, Minneapolis, Minnesota.

the plates and the mixture was swirled and allowed to incubate for 2 to 5 days at room temperature, and the colonies were counted.

To study the effects of presoaking grain, they were placed in water under a partial vacuum for 1 hour to displace air under the hull by water. Controls included tests where grains were soaked for the same duration, and grain not soaked and kept under normal atmospheric pressure prior to tests for germination. The grains were not allowed to dry prior to testing for germination.

In other tests, grains were soaked in water for 15 hours, dried for 24 hours, then tested for germination in Petri plates. Also, 150 grains that were wet, then dried were sown in soil in the greenhouse, and allowed to germinate, and compared with the same number of grains not soaked.

Experiments to determine the possible presence of germination inhibitors in hulls were made with hulls which were removed manually from the grains and ground to a number 40 mesh size. Approximately 4 gm amounts of the ground material were then extracted with 70 per cent ethyl alcohol or diethyl ether. Each sample was extracted three times for 15 minutes at 25° C using 25 ml amounts of the solvent per extraction.

Water extracts were prepared by extracting about 4 gm of dark hulls, ground to number 40 mesh size, with 100 ml of distilled water. The ground material was agitated in a Waring blendor for 6 minutes and filtered; 10 ml amounts of the filtrate were added to each Petri plate. The effect on development of the seedlings was determined after 4 days.

In some tests, hulls were removed, ground as described, and the dehulled grains were moistened. Each moistened grain was rolled in ground hulls and set in a Petri plate containing moist filter paper, for tests of germination.

RESULTS AND DISCUSSION

Germination and hull color. Apparently color of the hull was not correlated with percentage germination, since 37 per cent of the dark grains and 33 per cent of the light colored ones germinated; however, the rate of germination was reduced somewhat in dehulled grains treated with dark-colored hulls (Tables 1 and 2).

Germination and grain size. Forty-seven per cent of the large dark grains, and 53 per cent of the large light-colored grains germinated, compared with 29 and 28 per cent, respectively, for the small ones.

Germination of grains with hulls on and hulls removed. When the hulls were removed, germination averaged 71 per cent, approximately double the percentage germination of grains with the hulls on; the latter averaged 35 per cent (Figure 1).

Germination and presoaking grain under partial vacuum. The results are shown in Figure 1. Soaking the grain in water under partial vacuum reduced percentage germination considerably. Also, the dehulling of the grain increased germination percentages, regardless of treatments, in contrast to results reported by Johnson (7).

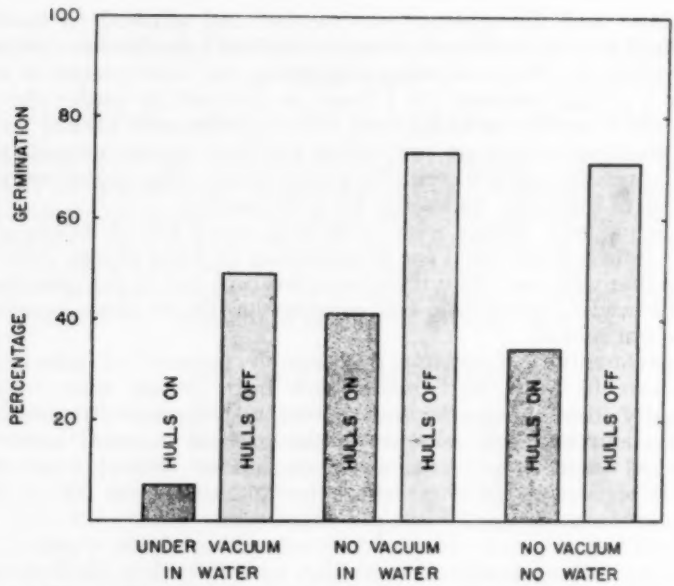

Figure 1. The percentage germination of wild oat grains when hulls were left on and when removed, under each of three treatments prior to tests for germination: Grains in water for 1 hour under partial vacuum, soaked for 1 hour but not under partial vacuum and when neither soaked nor under vacuum prior to tests made of germination. Percentages represent averages of 200 grains for each of 16 seed lots germinated in Petri plates.

Germination and alternate wetting and drying of grain. Grain that was wetted then redried germinated 5 per cent in Petri plates compared to 60 per cent, when not redried, with a seed lot that was 18 months old. In soil also, percentage germination was reduced by a wet-and-dry treatment of grain. Percentage germination was 15 for the wet-dry treatment, compared to 39 for the control in counts made 7 days after sowing; 9 days later the percentages were 44 and 69, respectively, for the two treatments.

Using a 3-year-old seed lot, it was found that the germination percentage of wet-and-dried grains was 55 compared with 90 for controls. However when grains were dehulled, it was found that the percentage germination was about 95 regardless of treatment. Thus it appears that the wet-and-dry treatments affected the caryopsis only when the hull was attached.

Stevens (11) found that freshly-ripened grains, or grains exposed outdoors (presumably under conditions of alternate wetting and drying) germinated poorly, whereas wild oats stored indoors at room temperature increased in germination fairly rapidly. In the work of the writers, it was found also that where 6-month-old grain averaged about 35 per cent germination, varying with the seed lot, 18-month-old grain germinated 60 to 70 per cent, and 3-year-old grains germinated more than 90 per cent, when grains were stored dry. This

increase in germination with dry storage has been cited by Crocker and Barton (4) for other fruits and seeds. Whether germination inhibitors in the hull (5, 6) or microflora present under the hull (2, 12) are involved, has not been established for wild oats.

Germination of grain coated with ground hulls. The major results are given in Table 1. It was found that 3 days after tests began, the grains coated with the ground, dark hulls were substantially lower in percentage germination than grains with hulls removed, but not as low as the percentage germination of grains with hulls still

Table 1. The effect on germination of wild oat grains of removing hulls, grinding them and coating dehulled grain with ground hulls, and ground hulls less alcohol or ether soluble portions, using dark and light colored grains and making counts after periods of 3 and 10 days.

Treatment of grains	Percentage germination per time period[a]			
	Dark-colored hulls		Light-colored hulls	
	3 days	10 days	3 days	10 days
Hulls on	22	69	30	53
Hulls removed	79	90	60	74
Hulls removed:				
Coated with ground hulls[b]	48	86	67	77
Coated with hulls extracted with alcohol[c]	44	83	66	82
Coated with hulls extracted with ether[c]	54	85	68	78

[a]Wild oat grains were tested for germination, in Petri plates, based on 200 grains, 10 plates of 20 grains per plate.

[b]Hulls were removed manually from grain and ground to number 40 mesh size.

[c]About 4 gm amounts of ground material were extracted with 70 per cent ethyl alcohol or diethyl ether. Each sample was extracted 3 times for 15 minutes at 25° C, using 25 ml of solvent per extraction.

attached. In contrast, after 10 days there was apparently no difference in the percentage germination between grains with hulls removed and grains coated with ground hulls, regardless of hull color. Thus, while hull color was not generally associated with the final percentage germination, there was an effect of dark hulls on rate of germination.

Also, the extracting of the ground, dark hulls with ether or alcohol did not alter the effect from that obtained with the unextracted, ground hulls. Thus it may be postulated that a substance was present in the dark hulls that delayed germination and that this substance was absent or less concentrated in light-colored hulls. In other tests, germination counts were made 4 and 12 days after tests were begun; the results were similar to those given in Table 1.

Germination of grain treated with hull extracts. Results are shown in Table 2. The percentage of seedlings having plumules about 3 cm long was greatest in the treatment where only hulls were removed, and the percentage of seedlings with plumules 2 cm long was lowest with the same treatment. The addition of water extracts from dark hulls to dehulled grain gave a percentage germination similar to that for grains with hulls on. Thus there may be a water-soluble substance present in the hulls of dark grains that delays the

Table 2. The effect of adding water extracts of dark-colored wild oat hulls on plumule length of dehulled grains.

Treatment of grains	Percentage seedlings in each group[a]			
	Approximate length of plumule in cm			
	0	1	2	3
Hulls on	27	17	45	11
Hulls removed, extract added[b]	25	21	44	11
Hulls removed	29	17	30	25

[a]Based on germination tests of 200 grains in Petri plates; 10 plates of 20 grains per plate.
[b]400 dark-colored hulls (3.7 gm dry weight) were ground, added to 100 ml distilled H_2O, mixed in Waring blendor for 6 minutes, filtered and 10 ml of filtrate added to each plate.

rate of germination or which temporarily inhibits seedling development. From this experiment and those with ground hulls and the wet-dry treatment of grains, it can be postulated that dormancy in the embryos could be attributed to water soluble substances in the hull that inhibit germination. A list of germination inhibitors present in seed coats and hulls of various seeds has been compiled by Evenari (6).

Relation of fungi to germination. The major fungi isolated from whole grains surface disinfected and cultured on acid PDA were Alternaria, Helminthosporium and Fusarium. Alternaria grew from 78 per cent of the dark hulled grains and from 74 per cent of the light ones. This fungus is very prevalent in cereal grains, and it is not unusual to find freshly harvested lots of wheat, for example, with 100 per cent of the grains infected by Alternaria. There is no evidence that it has any measurable effect on germination. *Helminthosporium sativum* PKB was isolated from 7 and 6 per cent, respectively, of the dark and light colored grains, but grew from 50 per cent of the grains of some lots. This fungus is known to be a pathogen of seedling and adult plants of various cereal crops (3), but there was no evidence in the present tests that it influenced dormancy of the grain.

Microflora from comminuted and diluted grains. On acid PDA, nongerminated grain yielded approximately 200,000 colonies of yeast per grain (15,000,000 colonies per gm), while germinated grain yielded 20,000 colonies of yeast per grain (1,500,000 per gm).

On malt-salt agar, nongerminated grains gave 125,000 yeast colonies per grain (9,375,000 per gm), and germinated grains yielded 2500 yeast colonies per grain (187,500 per gm).

The bacteria and yeast colonies on PDA were too numerous to count but those from nongerminated grains far outnumbered those yielded by germinated grains.

The nongerminated grains (at 48 hours incubation) had a much greater population of yeasts than had the germinated ones. Some of the grains listed at 48 hours incubation as nongerminated were not dead, but merely slow in germination because an equal number of nongerminated grain kept for an additional 2 days germinated about 50 per cent.

It is not known whether the higher count of yeasts in nongerminated grains was a cause or an effect of nongermination. Rapid growth of yeasts under the hull could use up oxygen, produce carbon dioxide, or produce toxic or stimulatory products, any of which could conceivably affect dormancy or germination.

SUMMARY

Thirty-two seed lots of wild oats were collected from Minnesota, North Dakota and Montana and tested for germination in relation to hull color, dehulling grain, hull extracts, wetting-and-drying grain, grain size, and microflora of grain.

The percentage germination of dark and light colored grains was about the same. Large grains germinated about 20 per cent higher than did small ones.

Dehulling grains increased germination percentages, on the average, from 35 to 70, regardless of hull color, when grains were germinated in Petri plates.

Grain in water under a partial vacuum prior to tests for germination increased in percentage germination from 7 to 49 by dehulling grain. Grain in water at normal atmospheric pressure prior to germination increased from 41 to 73 in percentage germination when grain was dehulled. With no pretreatment of grain, germination percentages increased from 34 to 71 upon dehulling the grain. Thus by dehulling grain germination percentages increased in all three treatments. Also the displacement of air by water substantially lowered germination percentages of grains with hulls still attached.

Wetting and drying grains prior to germination reduced the germination percentage considerably, both in Petri plates and in soil, indicating that a secondary dormancy might have been induced. However when dehulled seed was wet and redried the percentage germination was the same as that of the controls. Therefore the alternate wetting and drying affected the caryopsis only when the hull was attached.

Ground hulls or extracts from them did not influence percentage germination; however a water extract of the hulls of dark grains reduced the rate of germination.

Nongerminated grains yielded from 10 to 50 times the number of yeast colonies that were found in germinated grains, depending on the medium used. However, it was not clearly established whether dormancy of wild oats was attributed to substances normally produced in the hull or whether microflora or toxic substances from microflora within the hulls affected germination.

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Preliminary Studies of the Root System of *Kochia scoparia* at Hays, Kansas[1]

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KOCHIA (*Kochia scoparia* L.), also commonly called fire weed, is one of the most widespread annual weeds in Kansas and the Great Plains region. The origin of the weed in Kansas is obscure but it was introduced into the United States from Europe (1). The plant had been cultivated as an ornamental and apparently much of its present wide distribution is a result of escape from ornamental plantings.

Although a serious weed, kochia is often used as an emergency forage crop and some studies have been made to determine methods of culture and feeding value of the plant (2). An important factor in its potential use as forage is its ability to withstand drought and produce feed when cultivated crops fail and grasses are dormant.

Total precipitation at Hays, Kansas in 1956 was 9.21 inches, which was 13.54 inches below the 89-year average of 22.75 inches at that location. Except for a short period in the early part of July the entire growing season was extremely dry. Only 1.25 inches of rain was received from mid-July until October 1. Of this amount all except 0.45 inch, which fell August 10, occurred as light showers of less than 0.25 inch. Most of the vegetation normally used as forage was dead or dormant throughout most of the growing season. By September 15 it was strikingly evident that kochia was much more drought tolerant than sorghum or native grasses. These crops died or became dormant while the kochia remained green and continued limited growth. These studies were undertaken to determine whether physical characteristics of the kochia root system may, in part, account for the plant's ability to withstand drought.

MATERIALS AND METHODS

Four sites, representing different conditions for growth were selected for excavation and root examination. Plants on a heavy silt loam topsoil and silty clay loam subsoil were examined when growing (a) in a cultivated field in competition with grain sorghum, (b) in a scattered stand on summer fallow, and, (c) in a noncultivated area in competition with annual and perennial grasses. The fourth site was in a dense stand of kochia growing on deep alluvial soil.

Surface soil area in the sorghum field averaged about 1 square foot per weed, and at the beginning of the season approximately an equal number of sorghum plants were present in rows spaced 20 inches apart. The sorghum was planted on May 31 and the crop and the weeds emerged about June 5. The soil was not disturbed during the

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remainder of the growing season. In the summer fallow area the last cultivation prior to excavation was July 12. The other two sites were not cultivated during 1956.

Excavations to a depth of 8 feet were made on September 27, 1956 with power equipment. Soil profiles were removed in the vicinity of representative kochia plants and the root systems washed out as described by Weaver and Darland (6). A vertical section of soil 6 by 12 inches by 6 feet was removed from the sorghum field and a section 6 by 12 inches by 8 feet was taken from the bottom land site. Examinations for evidence of root penetration below the profile depth were made with a 4-inch soil auger.

RESULTS AND DISCUSSION

Although the crop and kochia emerged at the same time in the sorghum field the weed growth soon dominated the area. On July 19 a portion of the sorghum planting was hand weeded. Most of the crop plants were alive on that date yet no grain was produced in the weeded area. By August 15 sorghum in the weed infested area was dead while kochia remained green until the root studies were made (Figure 1).

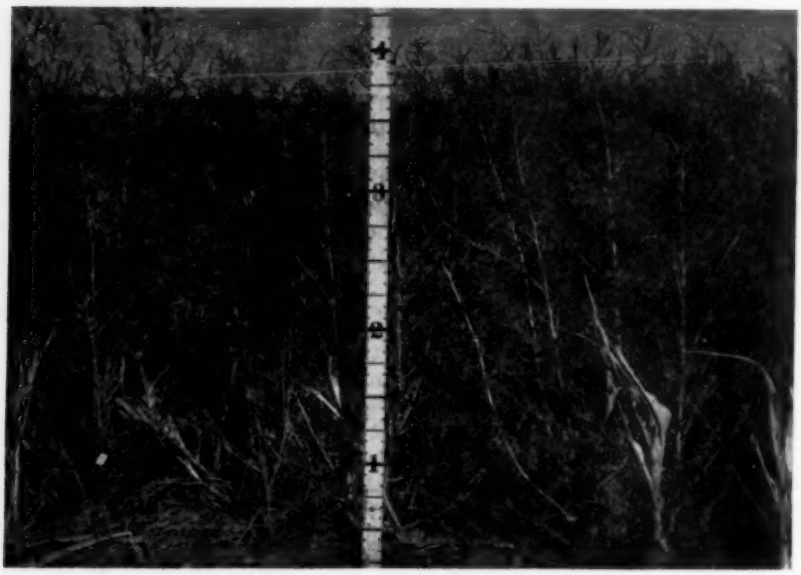

Figure 1. Kochia growing adjacent to excavation in the sorghum field. Note the dead sorghum plants in the foreground.

Figure 2 shows the roots obtained from the profiles. The notable lack of branching in the 6 to 24-inch zone of the sorghum field profile was probably due to a layer of heavy compact soil which restricted root growth. Moisture stress also may have affected root

development in that zone. Roots growing in the other sites exhibited a similar growth pattern, but the effect was not so pronounced.

After washing the soil from the roots it was evident that the full depth of penetration had not been determined. Soil samples taken in the sorghum field below 6 feet with the soil auger were examined to determine whether or not live roots were present. Each sample taken from 72 inches to 118 inches contained living roots. Since the sorghum plants were dead and no other plants were growing in the area it was assumed that the kochia roots extended to at least 118 inches. The plants attained this depth during a 115-day growing period.

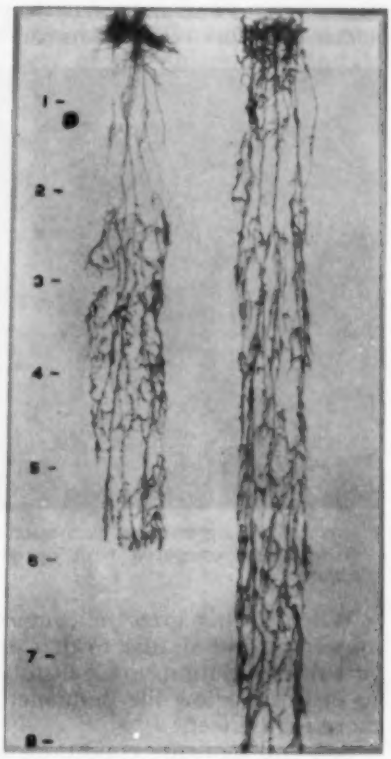

Figure 2. Root systems of kochia taken from 6 by 12 inch soil profiles; (left) sorghum field; (right) bottomland site. Numbers indicate profile depth in feet. Roots extended below depths indicated by the profiles.

Soil moisture determinations were not made at the time of sorghum planting but the depth of moist soil was estimated by using a soil probe. The indicated depth of soil moisture on May 28 was 33 inches. Since the area had produced a wheat crop the previous year which normally would have exhausted the available soil moisture, and the only moisture of consequence after wheat harvest did not penetrate below 33 inches, it was believed that this was the depth of available moisture. Precipitation after sorghum planting was not sufficient to penetrate below the first or second foot. It is obvious, however, that moisture available to kochia was present at considerably lower depths. At the time of the excavations, the soil was at or below the permanent wilting percentage from the surface down to at least 6 feet. Moist soil was found below the eighth foot down to maximum root penetration.

Kochia which grew in a sparse stand on land being summer fallowed assumed a bushy top growth rather than the upright growth found when it grew in a heavy stand and in close competition with sorghum (Figure 3). Examination of the root system likewise showed a different type of development. Roots penetrated at least 8 feet deep but also extended laterally for considerable distance. One root, growing about 4 inches below the soil surface, was traced laterally

for more than 8 feet from the plant. If it is assumed that widely spaced plants feed from a circular area, one kochia plant might be capable of drawing water from a cylindrical soil mass 16 feet in diameter and 8 or more feet deep. Additional investigations will be necessary before conclusions can be drawn.

Figure 3. Kochia growing at excavation site on summer fallowed land. Note bushy growth here compared with upright growth under competition shown in Figure 1.

When kochia grew in competition with grasses its root system appeared to be similar to that observed in the sorghum field. Moisture determinations made October 9, 1956, showed the soil moisture to be at or below the permanent wilting percentage to a depth of more than 6 feet.

Soil and moisture conditions on the bottom-land site were somewhat atypical. However, the excavation served to illustrate the potential root penetration and root development of kochia. Figure 2 shows the extensive system of roots obtained from the 6 by 12 inch profile. Additional roots were obtained in soil samples taken as much as 16 feet below the surface.

Few, if any, workers have reported that roots of annual plants penetrated so deeply into the soil. Even the 72 and 96 inches represented by the profiles appear to be rather deep vertical roots. Miller (3) summarized studies made from 1880 to 1937 on the extent of root penetration. He reported only one annual plant, wheat grown in Australia, that had vertical roots which exceeded 100 inches. Pavlychenko (4) and Pavlychenko and Harrington (5) reported on the extent of the total root system of several plants, but reported vertical penetration did not exceed 63 inches.

SUMMARY

1. Drought tolerance of kochia was evident in 1956 at Hays, Kansas. Soil excavations were made to study the extent of kochia

root systems and to determine the effect of four growth conditions on root development.

2. A 6-foot profile was removed from one upland site and an 8-foot profile was taken from the bottom-land site. Root penetration exceeded the profile depth in both locations. Maximum vertical root penetration was approximately 10 feet in the upland site and 16 feet in the alluvial soil. Lateral roots extended as much as 8 feet from plants growing in a scattered stand.

3. Soil moisture samples were taken to a depth of 8 feet adjacent to all excavations. The soil moisture was at or below the permanent wilting percentage to a depth of more than 6 feet wherever there was a dense stand of vegetation.

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The Leaching of Monuron from Lakeland Sand Soil. Part II. The Effect of Soil Temperature, Organic Matter, Soil Moisture, and Amount of Herbicide[1]

R. P. Upchurch and W. C. Pierce[2]

In Part I of the present study, the effects of amount, intensity, and frequency of simulated rainfall on the distribution of monuron [3–(*p*–chlorophenyl)–1,1–dimethylurea] in Lakeland sand soil were studied (9). Part I also indicated the general importance of leaching in herbicide usage. The present study includes consideration of soil temperature, soil organic matter, soil moisture content, and amount of herbicidal application as they influence monuron distribution.

Organic matter has been shown to be important in influencing the amount of leaching of substituted urea herbicides (2, 3, 4, 6). This has been attributed to the high degree of affinity which organic matter has for this group of chemicals (7). The mechanism of this affinity has not been elucidated. Sherburne, et al. have reported that the depth to which monuron leaches is inversely related to soil moisture percent prior to initiation of leaching (8). The factors of soil temperature and amount of herbicide have received little consideration in regard to their effect upon the distribution of herbicides in soils.

Materials and Methods

The same basic procedures were used for the experiments described herein as for a previous series of experiments (9). Soil columns 3 inches in diameter and 36 inches high were reconstituted from air-dry soil. Twenty-four hours after the addition of monuron [usually 40 lb/A, equivalent to 20.44 milligrams per column], simulated rainfall treatments were started. Twenty-four hours after the last addition of simulated rainfall, the columns were separated into six sections (0 to 2, 2 to 4, 4 to 8, 8 to 12, 12 to 24 and 24 to 36 inches) and analyzed chemically for monuron content. The method of analysis, which involved hydrolysis and spectrophotometric determination, has been described in detail (9). The same supply of Lakeland sand soil from Northwest Florida was used as for previous experiments.

The soil temperature studies were conducted under special conditions. An environmental control chamber (4 x 4 x 4 feet dimensions) was used for temperature and humidity control. Five experiments were conducted in which the temperatures were maintained successively at 5, 15, 25, 35, and 45 ± 0.5° C. The relative humidities for these temperatures were maintained between 50 and 60 percent.

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[2]First Lieutenants, United States Air Force.

For each temperature, three soil columns were placed in the chamber and 4 hours were allowed for the temperature of the soil to reach equilibrium with the temperature of the chamber before applications of water were started. Thermocouples had been placed in each column 9 inches below the soil surface with leads extending from this point out the bottom of the column. In all cases, the soil temperatures reached equilibrium with the chamber temperatures within 4 hours. Monuron had been applied to the surface of each soil column 20 hours prior to placement in the chamber. During this 20-hour period, an ambient temperature of 25 ± 3° C was maintained for the columns. Eight, ½-inch applications of simulated rainfall were made to each column at ½-hour intervals. At the time of application to the columns, the water had a temperature of 25 ± 1° C in all instances.

Organic matter content of soil is ordinarily considered to be an important factor in determining the amount of leaching of herbicides. As a convenient method of studying this factor in Lakeland sand soil, columns were constructed in which the 0 to 2-, 2 to 4-, and 4 to 8-inch layers of soil were altered in their composition. In one instance, the 0 to 2-inch layer was replaced with soil from the 24 to 36-inch layer. In a second instance, both the 0 to 2- and 2 to 4-inch layers were replaced with soil from the 24 to 36-inch layer. The third treatment involved the replacement of the 2 to 4-, and 4 to 8-inch layers with 0 to 2-inch soil. A fourth treatment without replacement was used for comparison. This series of modified columns provided a variation in organic matter content of the 0 to 8-inch soil layer. Probably other minor differences were introduced by this modification procedure. The average organic matter contents for the 0 to 8-inch layers of the four columns were calculated to be 1.44, 1.18, 0.99, and 0.87 percent. The organic matter content for the soil as it was found in the field was 1.44, 1.15, 1.07, 0.84, 0.70, and 0.68 percent for the 0 to 2-, 2 to 4-, 4 to 8-, 8 to 12-, 12 to 24-, and 24 to 36-inch layers, respectively. Each of the columns received a 40 lb/A rate of monuron and 4 inches of simulated rainfall. Each treatment was replicated twice.

Two levels of soil moisture were used to study the influence of soil moisture content on leaching of monuron. In one instance, air-dry soil having a moisture content of less than 0.3 percent was used. In the other instance, the soil was wet before the initiation of leaching by adding 4 inches of simulated rainfall to the column in ½-inch increments at ½-hour intervals. This was just enough moisture to wet the entire soil column and resulted in an average moisture content of 7.4 percent (air-dry, soil basis). Each of these columns received a 40 lb/A rate of monuron followed by 4 inches of simulated rainfall. The two treatments were replicated twice.

The effect of amount of herbicide application on leaching was studied using ten rates of application. The rates of ½, 1, 2, 4, 8, and 16 lb/A were replicated four times and the rates of 32, 64, 128,

and 256 lb/A were replicated twice.[3] A separate stock suspension of monuron was made for these experiments. As in other experiments, the monuron for each column was applied in a 5-milliliter volume of suspension. The series of rates used encompasses the range of rates over which monuron might be used from the lower rates for pre-emergence weed control, to the higher rates for soil sterility.

RESULTS AND DISCUSSION

The effect of soil temperature on leaching.

The data presented in Table 1 show that variations in soil temperature from 5 to 45° C had little effect upon the leaching of monuron from the 0 to 2-inch layer of Lakeland sand soil. Apparently, the entrance of herbicide into solution from solid particles is not greatly influenced by soil temperature where constant temperature rainfall is used. However, data for the 0 to 2-inch layers was found to give a highly significant fit when tested for a quadratic relationship. Further studies are needed to verify this relationship and to indicate the reason for it.

Table 1. The amount of monuron recovered from individual soil depths as influenced by soil temperature when leached with simulated rainfall.[a]

Soil temperature °C	Milligrams of monuron recovered[b]							Final depth wet soil—inches
	Depth of soil layer—inches						Total	
	0–2	2–4	4–8	8–12	12–24	24–36		
5	7.38	2.25	3.12	2.58	4.49	2.23	22.05	31.3
15	7.03	2.76	3.49	2.34	4.02	1.47	21.11	32.6
25	6.33	3.64	4.84	2.45	3.29	0.79	21.34	32.5
35	6.14	4.36	5.27	2.39	2.33	0.39	20.88	33.8
45	7.07	3.48	6.07	2.52	2.39	0.62	22.15	34.3

L.S.D.—for testing differences between means at the same depth.
.05 level of significance—1.14
.01 level of significance—1.54
C.V. —16 per cent

[a]Water applied in eight ½-inch increments at 30-minute intervals.
[b]Monuron applied = 20.44 milligrams per column.

The amount of monuron retained by the 2 to 4- and 4 to 8-inch layers of soil was greatly influenced by soil temperature. For the 2 to 8-inch layer, 79 percent more herbicide was retained at 35° C than at 5° C. The fact that increasing temperature from 35° to 45° C decreased rather than increased adsorption by the 2 to 4-inch layer is not understood. This is a real difference, however, as evidenced by the highly significant fit obtained when the data for the 2 to 4-inch layers were tested for a quadratic relationship. The linear components for both the 2 to 4- and 4 to 8-inch layers were found to be highly significant. The fact that the 8 to 12-inch layers retained essentially the same amount of monuron regardless of the soil temperature seems incompatible with the generalized effect of temperature described above. However, one must take into consideration

[3]Satisfactory recoveries of monuron were made from all of these treatments except for the three lowest amounts applied. Low percentage recoveries were obtained on the ½, 1, and 2 lb/A rates of application.

that less herbicide was available to the 8 to 12-inch layers at the higher temperatures than at the lower temperatures. Thus, the same absolute amount of herbicide was adsorbed from the percolating solution by the 8 to 12-inch soil layers at all temperatures even though the monuron solution concentration was less at the higher temperatures. By this analysis, it may be seen that increasing the temperature increases adsorption efficiency even in the 8 to 12-inch layers. The 12 to 24- and 24 to 36-inch layers played a passive part in establishing the final distribution of monuron in the columns. These layers acted as recipients of whatever material was passed to them from above and they had little opportunity for selectively removing material from percolating solution. Under field conditions, these layers might or might not play this role, depending upon the particular rainfall conditions involved. These results indicate that the removal of monuron from the 0 to 8-inch layer of Lakeland sand soil would be greater in the winter than in the summer. Soil temperatures might be expected to vary under field conditions in the 1 to 6-inch layer between the extremes used in this study.

The reason for an increase in the adsorption of monuron by sub-surface soil layers as temperature is increased over the range of 5 to 45° C is not known. The mechanisms of adsorption and the effects of environmental factors on the rate and total amount of adsorption are poorly understood for well defined systems (1). The lack of understanding is even greater for systems in which the adsorbant is ill defined as in the case of soil. However, some generalizations may be warranted for the present case. The fact that increasing temperature caused an increase in adsorption indicates that a chemical reaction was involved rather than a physical reaction such as would take place through van der Waals forces. However, the position of so-called activated adsorption in this system is not known (1). Further studies on the types of adsorption occurring in soils are needed. In such studies it would be desirable to know whether organic or inorganic colloids are involved.

It is possible that the increased solubility of monuron at higher temperature is also important in determining the degree of adsorption. This solubility effect would be opposite from the temperature effect reported above. Perhaps the effect of solubility in decreasing adsorption at higher temperatures accounts for the lowered adsorption by the 2 to 4-inch layer of soil at the 45° C temperature as compared with adsorption at the 35° C temperature.

The possibility that increasing temperature may increase the rate of percolation should be considered in studying the effect of temperature on herbicide distribution. One would expect an increase in temperature to increase the rate of percolation because of its effect upon the viscosity of water. An increase in percolation rate would decrease the adsorption of herbicide by the upper sub-surface soil layers. If such an effect was present, it was masked by the opposite main effect of temperature in bringing about an increase in adsorption.

No attempt was made in these studies to investigate the effect of the temperature of rainwater on leaching. Water at 25° C was used for each of the five soil temperatures. No information has been found on the temperature of rainwater, but it has been assumed that rainwater of a uniform and intermediate temperature would more closely approximate natural conditions than varying the rainwater the same as the soil temperature. The use of a constant temperature rainwater may have brought the upper layer of soil to the temperature of the rainwater and, thereby, reduced or eliminated, for the upper soil layer, the soil temperature variables under study. Although this same phenomenon may take place under natural conditions, the exact influence of the soil temperature in the upper soil layer and the temperature of rainwater on leaching should be investigated.

The effect of the source of soil used for the 0 to 2-, 2 to 4-, and 4 to 8-inch layers on leaching.

Apparently, organic matter is extremely effective in preventing monuron from being leached by simulated rainfall (Table 2). The

Table 2. The amount of monuron recovered from individual soil depths as influenced by the source of the soil used for 0–2, 2–4, and 4–8-inch layers when leached with simulated rainfall.[a]

Average organic matter content of 0–8-inch layer—per cent	Field depth of soil, in inches, used to reconstitute three column layers			Milligrams of monuron recovered[b]							Final depth wet soil—inches
				Depth of soil layer—inches						Total	
	0–2	2–4	4–8	0–2	2–4	4–8	8–12	12–24	24–36		
1.44	0–2	0–2	0–2	7.26	5.50	4.80	0.22	0.41	0.37	18.56	30.5
1.18	0–2	2–4	4–8	8.14	3.99	3.33	1.78	2.27	0.69	20.20	31.2
0.99	24–36	2–4	4–8	3.09	3.85	3.77	2.43	4.62	2.44	20.20	33.6
0.87	24–36	24–36	4–8	2.34	0.56	3.97	2.92	6.13	3.50	19.42	34.4

L.S.D.—for testing differences between means at the same depth.
.05 level of significance—1.25
.01 level of significance—1.96
C.V. —16 per cent

[a]Water applied in eight ½-inch increments at 30-minute intervals.
[b]Monuron applied = 20.44 milligrams per column.

0 to 2-inch layer of soil retained 40 percent of a 40 lb/A rate of monuron where the regular 0 to 2-inch soil was used, compared to 12 percent when 24 to 36-inch soil was substituted for the 0 to 2-inch soil. This difference was even greater in the 2 to 4-inch layer where the regular 2 to 4-inch soil retained 20 percent of the monuron applied, compared to 3 percent when 24 to 36-inch soil was substituted for the 2 to 4-inch soil. Conversely, where the organic matter in the 0 to 8-inch horizon was increased over the regular complement by substituting 0 to 2-inch soil for the 2 to 4- and 4 to 8-inch layers, a high amount of monuron retention was observed (95 vs. 76 percent). The amount of monuron retained in the 0 to 8-inch layer varied from 35 to 95 percent, depending upon the amount of organic matter found in that layer.

The effect of soil moisture content on the rate of leaching.

According to the data presented in Table 3, it appears that soil moisture content has little or no influence on the leaching of monuron. Possibly, the higher moisture content impeded leaching to a slight degree, since 34 percent of the monuron applied was retained in the 0 to 2-inch layer for the wet treatment, compared to 27 percent for the dry treatment.

Table 3. The amount of monuron recovered from individual soil depths as influenced by the soil moisture content prior to initiation of leaching.[a]

Soil moisture content prior to initiation of leaching	Milligrams of monuron recovered[b]							Final depth wet soil—inches
	Depth of soil layer—inches						Total	
	0–2	2–4	4–8	8–12	12–24	24–36		
Air dry	5.64	3.67	3.99	2.16	3.96	1.47	20.89	35.5
7.4 per cent (air-dry soil basis)	7.12	3.63	3.83	2.34	3.12	1.20	21.24	—[c]

[a]Water applied in eight ½-inch increments at 30-minute intervals.
[b]Monuron applied = 20.44 milligrams per column.
[c]An average of 223 milliliters of water drained from each of the prewet soil columns during leaching.

There are several pathways whereby soil moisture content might be important in influencing the leaching or retention of herbicides in soil. Possibly some of these factors might be much more important than indicated by the data in Table 3, since two of them, under the particular conditions of this experiment, might have acted in opposite directions and cancelled one another. The soil moisture content probably influences the rate of movement of added water to a degree which is dependent upon the specific moisture content involved. For the present experiment, it is postulated that the rate of movement of percolating solution would be slower in the wet treatment than in the dry treatment, resulting in greater retention of monuron by the upper soil layers in the case of the wet treatment. The fact that the percolating solution which fills the soil interstices contains herbicides in solution in the case of the dry soil treatment probably causes a greater retention of monuron in the upper soil layers by the dry treatments. The interstices of the wet treatment would already be filled by moisture containing no herbicide and the percolating solution containing monuron would be excluded, to a degree, from the adsorption sites of the interstices. Another potential cause for the decreased retention of monuron by the upper soil layers is the possibility that the concentration of monuron in the percolating solution may become more dilute as the percolating solution moved through the pre-wet column. Pre-wet soil probably has a greater retention capacity for organic molecules than does air-dry soil, and this relationship would cause the wet treatment to retain more herbicide in the upper soil layers than the dry treatment. From the present experiment, there is no way of knowing the real importance of the four factors described above. Therefore, further experimental work is needed.

The effect of amount of herbicide application on leaching.

The data of Table 4 show that each two-fold increase in monuron applied, beginning at ½ lb/A and ending at 256 lb/A, resulted in an increase in the monuron content at each soil depth, providing monuron had been previously found at the depth under consideration. The exception for the 8 lb/A rate at 24 to 36-inches may be attributed to experimental error. The percentage distribution of monuron among the six soil depths for the varying rates of application is probably of more interest than the absolute distribution. The following discussion is based upon the amount of monuron recovered from various soil layers being expressed as a percent of the total monuron recovered for the entire column. The rate at which the 0 to 2-inch soil layer had the lowest retention percentage was 32 lb/A (34 percent retention). Decreasing the amount applied progressively increased the retention percentage by the 0 to 2-inch layer until a high of 93 percent was retained for the ½ lb/A rate. Likewise, increasing the amount applied above 32 lb/A progressively increased the retention percentage for the 0 to 2-inch layer until 59 percent was retained when the 256 lb/A rate was used. Since low percentage recovery was obtained for monuron from the ½, 1, and 2 lb/A treatments, the above statements are altered to a degree if one expresses the results as percent of monuron applied. Using percent theoretical as a base reference, the minimum percentage retention for the 0 to 2-inch layer is obtained with the 16 lb/A treatment (35 percent). Decreasing the amount applied increases the percentage retention by the 0 to 2-inch layer (50 percent for ½ lb/A). It seems likely that the true percentage of monuron retained by the 0 to 2-inch layer for the ½ lb/A treatment is between the values of 93 and 50, which are obtained by expressing the results as percent of that recovered and applied, respectively.

Table 4. The amount of monuron recovered from individual soil depths as influenced by the rate of herbicide applied when leached with simulated rainfall.[a]

Rate of monuron		Milligrams of monuron recovered							Final depth wet soil—inches
		Depth of soil layer—inches						Total	
Lb/A	Mg/column	0–2	2–4	4–8	8–12	12–24	24–36		
½	0.26	0.13	0.01	0.00	0.00	0.00	0.00	0.14	33.4
1	0.51	0.26	0.06	0.03	0.00	0.00	0.00	0.35	32.7
2	1.02	0.44	0.17	0.06	0.01	0.02	0.00	0.70	32.7
4	2.05	0.91	0.39	0.29	0.14	0.26	0.19	2.18	32.6
8	4.09	1.92	0.58	0.47	0.26	0.46	0.16	3.85	32.0
16	8.16	2.88	1.48	1.65	0.65	0.86	0.30	7.82	32.6
32	16.35	6.55	3.72	4.65	1.43	2.55	0.38	19.28	31.7
64	32.71	14.40	6.83	8.61	3.17	3.47	0.58	37.06	31.3
128	65.41	35.31	8.81	11.45	3.39	7.12	1.54	67.62	32.2
256	130.83	76.89	11.27	20.76	6.13	12.15	2.23	129.43	31.7

[a]Water applied in eight ½-inch increments at 30-minute intervals.

Apparently, the 0 to 2-inch layer of Lakeland soil has a capacity for tightly adsorbing amounts of monuron on the order of ½ to 2 lb/A. Studies using rates of this magnitude would be expected to

lead to the conclusion that monuron is quite resistant to leaching (2, 4). Conversely, studies using amounts on the order of 20 to 40 lb/A would lead to the conclusion that monuron is more readily leached than indicated by studies using only the lower amounts. The reason for increased retention percentage for the 0 to 2-inch layer when the monuron rate of application is increased from 32 to 256 lb/A might be attributed to a limitation imposed by the solubility of monuron. Assuming that monuron is soluble in water to the extent of 240 ppm at 25° C, one may calculate from Table 4 the degree of saturation of the water as it leaches below the ¼-inch top layer. Assuming that the 0 to 2-inch layer adsorbs an amount of herbicide from the percolating solution equal to that adsorbed by the 2 to 4-inch layer, the degree of saturation of the leachate for the 256 lb/A treatment, as it leaves the top ¼-inch soil layer, is calculated to be 57 percent. Actually, the percentage would be somewhat higher since the 0 to 2-inch layer contains more organic matter than the 2 to 4-inch layer and undoubtedly adsorbs more monuron. At such a degree of saturation, further increases in monuron concentration of the percolating solution might be expected to be progressively more difficult.

The amount of monuron extracted from the percolating solution by the 2 to 12-inch layer of Lakeland sand soil is directly proportional to the amount of monuron entering that layer (Figure 1).

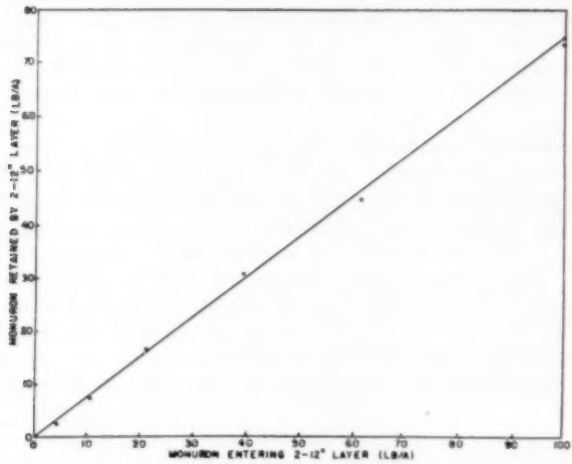

Figure 1. The effect of amount of monuron entering the 2 to 12-inch soil layer on the amount of monuron adsorbed by that layer (calculated from Table 4).

This proportionality was found for amounts of monuron entering the 2 to 12-inch soil layer up to at least 100 lb/A. Since this relationship was derived using a constant amount of leaching solution, it may be concluded that adsorption by subsurface soil layers is directly proportional to concentration of monuron in the percolating solu-

tion. The range over which the relationship exists and the rather steep slope describing the proportionality indicates that the subsurface layers of Lakeland sand soil have a very large capacity for adsorbing monuron. A similar concentration relationship was found by Weaver when he studied the adsorption of 2,4–dichlorophenoxyacetic acid on cationic exchange resins (10).

Indications concerning the general distribution process.

The results of this study provide further evidence that the distribution of monuron in soil is a two-step process with the first step occurring in two ways. Step I-A involves the entrance of herbicide into solution from solid herbicide particles. Normally, these particles would be on the soil surface. Step I-B involves the entrance of herbicide into solution from that which is adsorbed by or on soil particles. Step II involves the adsorption of herbicide from percolating solution by the soil. This step may include an equilibrium reaction in which the point of equilibrium and the equilibrium attainment rate may be important. A previous report showed that Step I-A is influenced to a remarkably small degree by the rate of passage of leaching solution, when one considers the low water solubility of monuron (9). This same report showed Step I-A to be influenced by amount of rainfall and by length of time between applications of simulated rainfall.

The general concept in the literature indicating that the solubility of a herbicide gives a key to leachability needs to be re-evaluated in terms of the two steps involved in leaching (4, 5). A single experiment is needed in which inorganic and organic chemicals, comprising a wide range of solubilities, are compared with respect to their leachability.

No evidence was collected in the previous study or in the present one concerning the factors affecting the rate of Step I-B. In the previous study, Step II (adsorption of herbicide from percolating solution) was shown to be influenced by the rate of passage of the percolating solution, as well as by the total amount of solution percolated. The present study has shown that Step II is influenced in direct proportion to the concentration of herbicide in the percolating solution and the temperature of the soil matrix. Using an indirect technique, the amount of organic matter was shown to be important in influencing Step II in the leaching of monuron.

SUMMARY

The effects of soil temperature, organic matter, soil moisture, and amount of herbicide application on the leaching and retention of monuron in Lakeland sand soil were studied. Soil columns 3 inches in diameter and 36 inches high were reconstituted from air-dry soil, using metal pipe sections to contain the soil. Monuron was applied to the surface of each column at a rate of 40 lb/A except where the amount of herbicide application was studied. Following the application of simulated rainfall to the columns, they were disassembled, and the soil from the six sections (0 to 2, 2 to 4, 4 to 8, 8 to 12, 12

to 24, and 24 to 36 inches) of each column was analyzed chemically for monuron content.

Soil temperatures from 5 to 45° C had little influence on the amount of monuron leached from the 0 to 2-inch soil layer. Temperature was quite important in affecting the amount of monuron retained by the 2 to 4- and 4 to 8-inch soil layers. Greater amounts were retained at the higher temperatures.

Soil organic matter was found to have a large effect upon the leaching of monuron. As the average organic matter in the 0 to 8-inch soil layer was increased from 0.87 to 1.44 percent, the amount of monuron retained was increased from 35 to 95 percent.

Whether the soil was at air dryness or saturated with water had little influence upon leaching of monuron.

The amount of monuron retained in the 0 to 2-inch section, using 4 inches of rainfall, expressed as percent of that applied, varied considerably according to the amount of monuron application. The minimum percentage retention by the 0 to 2-inch layer (34 percent) was obtained at an application rate of 32 lb/A monuron. Rates above and below 32 lb/A gave increasing degrees of retention by the 0 to 2-inch layer.

The four factors studied were analyzed in terms of their effect on two postulated leaching steps; I, the entrance of herbicide into solution and II, the adsorption of herbicide from percolating solution. The data indicate that Step II is affected by soil temperature, organic matter content, and the concentration of the percolation solution.

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Toxicity and Efficiency of Selected Herbicides on Representative Ornamental Plants[1]

DUNCAN G. BIRDSELL, DONALD P. WATSON, and BUFORD H. GRIGSBY[2]

THE use of herbicides among nursery crops has been practiced only to a limited extent. Possibly this is because: slight herbicidal damage is serious in an expensive crop of nursery plants; the diversity of plants in a nursery makes it difficult to find suitable selective herbicides; the relatively small area of many nurseries makes cultivation and hand hoeing more practical than for large acreages; and damage to foliage of nursery crops makes the plants unsaleable whereas in farm crops foliage damage is less significant.

Recommendations for weed control in field rows of nursery stock as given by Shaw et al. (28) include applications of 2,4–dichlorophenoxyethyl sulfate (sesone) or isopropyl N–(3–chlorophenyl) carbamate (CIPC) for non-directional spraying, and 4,6–dinitro-ortho secondary butylphenol (DNBP) or pentachlorophenol (PCP) in aromatic oil for directional spraying.

The purpose of the present project was to evaluate five of the more recently introduced herbicides for weed control and for toxicity to selected nursery plants in field plantings.

METHODS AND MATERIALS

The following seven species of ornamental plants were planted for testing with five herbicides: 2-year old Pfitzer juniper *(Juniperus chinensis pfitzeriana);* 2-year old Japanese yew *(Taxus cuspidata);* 1-year old Amur privet *(Ligustrum amurense);* 2-year old Tatarian honeysuckle *(Lonicera tatarica);* 1-year old spiraea *(Spiraea bumaldi* cv. Anthony Waterer); 1-year old myrtle *(Vinca minor);* and 1-year old Baltic ivy *(Hedera helix baltica).*

All planting took place between May 14 and June 10, 1956, using a randomized plot design with three replications per herbicide. Units within the plot consisted of seven shrubs spaced 3 feet apart. Rows were spaced 8 feet apart and units within the row spaced 7 feet part.

The two ground covers, *Vinca* and *Hedera,* were tested in rows separate from the shrubs with a randomized plot design and three replications. Units within the plot consisted of 8 plants spaced 1 foot apart in a rectangular pattern. Rows were 8 feet apart and units within the row were 4.5 feet apart.

Fifty pounds of 12–12–12 fertilizer were applied to the entire planting on June 15 using a band pattern around each plant.

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The following treatments were applied:

(a) 3–(3,4–Dichlorophenyl)–1–methyl–1–*n*–butylurea (Neburon) sprayed at the rate of 2 lb/A;

(b) 2,4–Dichlorophenoxyacetamide (2,4–D amide) applied at the rate of 2 lb/A;

(c) 2–Chloro–4,6–bis (diethylamino)–*s*–triazine (CDT) applied at the rate of 8 lb/A;

(d) 2,3,6–Trichlorobenzoic acid (2,3,6–TBA) applied at the rate of 2 lb/A;

(e) 2–(2,4,5–Trichlorophenoxy)ethyl 2,2–dichloropropionate (erbon) applied at the rate of 80 lb/A;

(f) No treatment.

Herbicides were applied to the ground covers on July 12 and to the shrubs on July 21 using a hand sprayer with T-jet nozzles No. 6503, 30 pounds pressure, and at the rate of 65 gallons per acre. Herbicides were applied as over-all sprays with a boom providing coverage of the soil 2 feet on either side of the row.

The shrubs were observed for herbicidal toxicity after 2, 5, and 10 weeks. Injury to shrubs was rated on an ascending numerical scale ranging from 1 to 5 with a grade of 1 indicating no plant damage and a grade of 5 indicating death of the plant. Sixty-five days after treatment photographs were made of representative plants indicating herbicidal injury and control of weeds. Four days later measurements were made of stem elongation of privet, honeysuckle, and yew for an index of herbicidal toxicity. Weed counts, in sample areas of 40 square feet, were made approximately 1 month after treatment. This was followed by weed counts, of sample areas of 30 square feet, 2 months after treatment.

RESULTS

The data on degree of toxicity of the herbicides to the newly transplanted shrubs are summarized in Table 1. The epinasty exhibited by all plants when treated with 2,4–D amide paralleled typical 2,4–D effects on plants as noted by Zimmerman and Hitchcock (34) and by Tukey et al. (32). Chlorotic conditions, as noted in juniper and yew, have been observed previously by Hamner and Tukey (12) following

Table 1. Toxicity indexes of herbicides applied to newly planted shrubs and ground covers 5 and 10 weeks after treatment.[a]

Ornamental	2,4-D amide		CDT		Neburon		2,3,6-TBA		Erbon		Not treated
	5	10	5	10	5	10	5	10	5	10	
Shrubs											
Juniper	1.62	1.14	1.10	1.14	1.19	1.09	3.81	2.02	3.72	2.33	1.00
Yew	1.67	1.00	1.57	1.15	1.43	1.15	3.91	3.62	2.81	3.32	1.00
Privet	1.19	0.80	3.14	1.77	1.14	0.80	3.86	2.52	3.76	2.47	1.00
Honeysuckle	1.09	1.33	1.00	1.14	1.00	1.23	1.09	1.81	3.00	3.57	1.00
Spirea	1.00	1.00	1.09	1.15	1.00	1.36	1.52	1.47	4.14	3.32	1.00
Ground covers											
Vinca	1.22	1.00	1.00	1.33	1.06	1.00	4.00	4.33	3.22	4.33	1.00
Ivy	4.00	4.67	3.67	4.00	2.61	2.67	2.50	3.17	4.78	5.00	1.00

[a]Rating scale: 1 = no injury, 5 = killed.

applications of 2,4–D sprays to woody plants. All of the plants sprayed, except established plants of privet, assumed normal appearance and growth after 1 or 2 months. Other woody plants on which 2,4–D has been applied have exhibited this recovery also (3, 4). Both groups of yews were stunted by the 2,4–D amide sprays, but the great reduction in annual growth in the established privet may have been caused by some other factor. Pridham and Stangler (26) also reported that spraying yews with amine salts of 2,4–D inhibited their growth.

Apparently CDT was readily absorbed by plant foliage because five of the six species of shrubs quickly showed chlorosis, indicating an inhibition of chlorophyll formation. Possibly junipers were resistant to this chemical in some manner similar to that reported for cotton, corn and snapbeans (1). Growth measurements indicated that in addition to the severe chlorosis on yews, growth was greatly retarded.

Neburon generally showed little toxicity to the ornamental plants, and the injury was similar to that from low dosages of monuron, a closely related compound. Applying monuron at rates ranging from ½ to 2 lb/A to yew, rose, forsythia, mock orange, Japanese barberry, red pine, jack pine, and rhododendron has been reported to give little or no injury by Pridham (25), Kuntz (17), Chadwick et al. (8) and by Ticknor and Bobula (31). The slight chlorosis on yew was similar to injury caused by other urea herbicides that have been reported to be absorbed primarily through the roots (20).

Privet, yew and juniper exhibited responses to 2,3,6–TBA similar to those previously noted on tomato by Zimmerman and Hitchcock (35). It was reported that the herbicide was readily absorbed by the leaves and moved rapidly to the growing tips where the main damage was concentrated and that high concentrations of the chemical inhibited growth. Honeysuckle and spiraea, although injured, showed some degree of tolerance. The use of 2,3,6–TBA at identical rates against brush of oak, poplar, ash, hawthorne, willow, wild rose, hazel, and dogwood has been reported by Playfair (23) to produce extensive foliar damage to all species except dogwood.

The initial moderate to severe injury to all shrubs from applications of erbon to soil about the base of the shrub, conformed with the previous observations of Swezey (30). Although both of the components of erbon are reported to be readily translocated (2, 9), initial observations indicated that damage was largely localized in areas of direct spray contact. Foliage may have been killed too quickly for translocation to take place or mid-summer reduction in growth may have prevented rapid translocation of the chemical throughout the plants. Later observations did show toxicity of the chemical throughout the plants indicating root absorption. Definite stunting of cotoneaster, privet, and yew plants parallels stunting of cotton plants by applications of the same herbicide (30). Late season recovery by some of the established plants indicated that a larger plant does overcome the effects of the chemical in time or that many of the roots are below the area in which the herbicide is still located.

Treatments of the ground covers with herbicides produced injuries similar to those on the shrubs. Vinca showed resistance to CDT parallel to that of juniper. Neburon continued its pattern of little or no injury. With the exception of 2,3,6–TBA ivy was more seriously damaged by the treatments than was Vinca (Table 1). The less extensive root system and the concentration of the roots near the surface of the soil in the ivy plots possibly accounted for the serious injury pattern.

The grass weed population within the plots was mainly large crabgrass *(Digitaria sanguinalis)*, small crabgrass *(Digitaria ischaemum)*, stinkgrass *(Eragrostis cilianensis)*, and tickle grass *(Panicum capillare)*. The broad-leaved weed population was mainly rough pigweed *(Amaranthus retroflexus)*, prostrate pigweed *(Amaranthus graecizans)*, lamb's quarters *(Chenopodium album)*, prostrate spurge *(Euphorbia supina)*, sandwort *(Arenaria serpyllifolia)*, purslane *(Portulaca oleracea)*, shepherd's purse *(Capsella bursa-pastoris)*, and dandelion *(Taraxacum officinale)*.

Table 2 and Figure 1 indicate excellent control of broad-leaved weeds with 2,4–D amide up to 8 weeks with a decided increase of small broad-leaved weeds at the end of 2 months. These results conform with the known toxicity of 2,4–D compounds to broad-leaved weeds. Although 2,4–D amide partially controlled grass weeds, the grasses were of major importance after 65 days (Figure 1). Applications of 2,4–D to grass seeds or seedlings have not produced high mortality unless high concentrations have been used (21, 24). Other phenoxy compounds have been reported to give effective weed control at rates ranging from 4 to 6 lb/A by several workers (6, 16, 19), but lower rates of these compounds have not proven successful (7, 11). Although rainfall during July and August was high, the toxicity of 2,4–D amide on weeds persisted for 2 months. Previous screening with this material had revealed its ability to resist leaching.

Table 2. Weed counts as percent of untreated plots 4, 8 and 10 weeks after application of herbicides.

Herbicide	Appl. lb/A	Weeks after treatment								
		4 weeks			8 weeks			10 weeks		
		Broad-leaved	Grass	Total	Broad-leaved	Grass	Total	Broad-leaved	Grass	Total
		%	%	%	%	%	%	%	%	%
2,4-D amide	2	5.9	25.3	16.6	28.3	37.6	32.9	9.3	53.0	31.1
CDT	8	8.0	34.3	21.1	8.5	44.4	26.4	5.1	73.3	39.2
Neburon	2	16.1	37.9	26.7	17.1	70.6	43.8	51.3	84.9	68.1
2,3,6–TBA	2	10.1	45.6	27.8	48.1	92.5	70.3	43.0	90.7	66.8
Erbon	80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

CDT showed excellent control of broad-leaved weeds for 10 weeks, second only in effectiveness to erbon (Table 2). Only fair control of grass weeds was achieved. Previous tests with CDT at 8 lb/A has been reported to give 89 percent and 83 percent control of weeds after 4 and 8½ weeks respectively (1), as compared with the present results of approximately 79 percent and 74 percent after

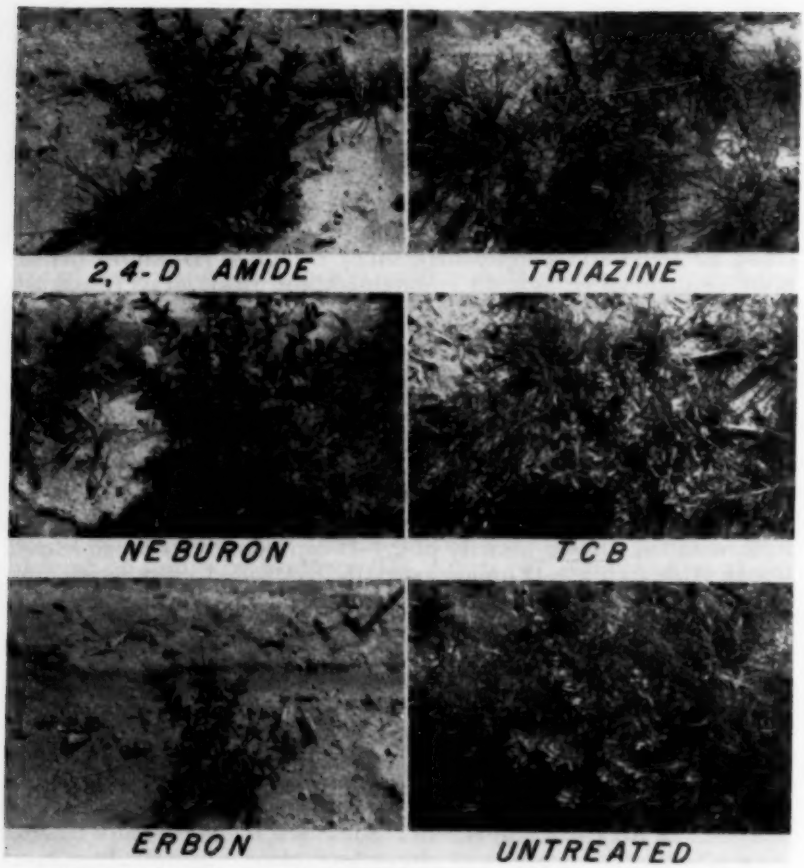

Figure 1. The effects of five herbicides upon weeds and privet 65 days after application.

4 and 8 weeks, respectively. Percentage differences could be accounted for by composition of weed population, amount of rainfall, soil type, or prevailing temperatures.

The amount of weed control in the present experiment using neburon was low compared with that obtained with other substituted urea herbicides by Holm and Gilbert (15) and by Hemphill (13, 14). These workers obtained satisfactory control of both broad-leaved and grass weeds with applications of from 2 to 2.5 lb/A of monuron and fenuron. In spite of neburon being recommended as an herbicide for crabgrass by Carlson (5) little control was exhibited. Possibly the low solubility of this material in water caused uneven coverage and spotty weed kill.

2,3,6–TBA gave good control of broad-leaved weeds after 1 month (Table 2), but was unsatisfactory in other respects. Other reports have indicated better control of broad-leaved weeds than of grass

weeds (27, 33). Residual activity of 2,3,6–TBA in soil 2 months after spraying has been observed by Ferrant et al. (10), and Table 2 shows small residual effects after an identical time lapse.

As indicated, erbon gave complete weed control on all plots for at least 10 weeks. Combining the 2,4,5–T radical, with its effectiveness against broad-leaved weeds (22), and the 2,2–dichloropropionic acid radical, with its effectiveness against grass weeds (29), produced good general weed control. Earlier trials by Swezey (30) showed that one application of erbon gave good control of weed growth for one growing season in areas of moderate rainfall.

SUMMARY

All of the plants exhibited epinasty from sprays of 2,4–D amide with junipers and yews also showing slight chlorosis. However, all except ivy showed complete recovery within 1 to 3 months. Most of the ivy plants were dead after 11 weeks.

CDT caused moderate to severe chlorosis on yew, privet, and ivy within 3 weeks. Slight chlorosis was exhibited by honeysuckle, and spiraea with juniper and vinca being uninjured. Ivy remained in poor condition after 11 weeks, but the other plants showed partial or complete recovery by then.

No toxicity to plants from neburon was evident except for slight chlorosis on ivy and yew.

2,3,6–TBA showed immediate damage to all plants with injury being concentrated in the growing tips of the plants. Juniper, yew, privet, cotoneaster and vinca all showed severe epinasty of leaves, tip dieback, and either chlorosis or necrosis of leaves. Honeysuckle, spiraea, and ivy exhibited slight chlorosis and necrosis of leaves from the spray.

Overall toxicity to plants was greatest from erbon. Severe localized browning of foliage on all plants was observed within 3 weeks of treatments. Within 5 weeks general browning and chlorosis of leaves was noticed on all plants. Eleven weeks after the treatments all of the ivy plants were dead, with some fatalities also observed in other species. Recovery late in the season was exhibited by established plants of juniper and yew.

Best overall weed control was exhibited by erbon, followed by that from 2,4–D amide, CDT, neburon, and 2,3,6–TBA.

Complete freedom from weeds was observed on plots sprayed with erbon for a period of 10 weeks after treatments.

2,4–D amide controlled approximately 84 percent of the weeds 1 month after treatments with excellent broad-leaved weed control and fair grass weed control. Observations 2 months after treatments showed some regrowth of broad-leaved weeds and abundant grass populations.

CDT controlled approximately 79 percent of the weeds 1 month after treatments with excellent broad-leaved weed control and fair grass weed control. Observations 2 months after treatments showed continued excellent broad-leaved weed control and some reduction in the grass weed population.

With neburon approximately 72 percent of the weeds were controlled 1 month after treatments with good broad-leaved weed control and fair grass weed control. Observations 2 months after treatments showed good broad-leaved weed control and poor grass weed control.

Approximately 73 percent weed control was obtained with 2,3,6–TBA 1 month after treatments with good broad-leaved weed control and poor grass weed control. Observations 2 months after treatments showed poor control of both broad-leaved and grass weeds.

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The Effects of Fresh Water Storage on the Germination of Certain Weed Seeds. III. Quackgrass, Green Bristlegrass, Yellow Bristlegrass, Watergrass, Pigweed, and Halogeton[1]

V. F. Bruns and L. W. Rasmussen[2]

Previous studies by Bruns and Rasmussen (1, 2) showed that the longevity of the seeds of certain noxious weeds may range from several months to 5 years or more when stored in fresh running water. In order to gain information of this nature on additional weed species, a third test was initiated on April 4, 1952. The results of this study are reported herein.

Methods and Materials

Except for the kind of weed seeds, the same methods and materials as previously described (1, 2) were used. Seeds of quackgrass (*Agropyron repens* (L.) Beauv.), green bristlegrass (*Setaria viridis* (L.) Beauv.), yellow bristlegrass (*Setaria lutescens* (Weigel) F. T. Hubb), watergrass (*Echinochloa crusgalli* (L.) Beauv.), pigweed (*Amaranthus retroflexus* L.), and halogeton (*Halogeton glomeratus* C. A. Mey.) (black seeds) were collected from fields. Nine thousand seeds of each species were divided into sample lots of 100 seeds and placed in individual Lumite screen bags (36-mesh) which were sewed with nylon thread. Six bags, each containing 100 seeds of the different weed species, were grouped to form composite samples for later germination studies. On April 4, 1952, 15 composite samples were fastened individually by means of brass bolts and nuts to each pair of arms of three separate pipe standards. Holes were drilled approximately 3 inches apart in the arms for this purpose.

The standards were constructed from ½-inch galvanized iron pipe in the form of an inverted T-on-T and attached at 20-foot intervals to the handrail of the catwalk at the fish screens in the Chandler Power Canal, Prosser, Washington. The seeds were held at both 12- and 48-inch depths in the water. Water temperature in the canal was recorded at frequent intervals throughout the storage period.

Composite samples from both the 12- and 48-inch depths were removed from each standard for germination studies at 3-month intervals over a period of 33 months. After 33 months, reconstruction of the Power Canal and fish screens disrupted and ended this test. Upon removal of composite samples, the seeds which appeared sound were placed between moist blotter papers in open, sterilized culture dishes and held in a germinator (68°–72° F.) for 4 weeks. At the same time, comparative germination studies were made on seeds

[1]Studies conducted at the Irrigation Experiment Station, Prosser, Washington. Published jointly by the U. S. Department of Agriculture and the Washington Agricultural Experiment Stations. Scientific Paper No. 1618, Washington Agricultural Experiment Stations, Pullman. Project No. 951.

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(2 x 100) of the same species and source which were dry-stored in glass bottles at room temperature. The seeds were not scarified. Determination of longevity rather than optimum germination was the main objective. Therefore, provision of light and alternating temperatures for germination of the different seeds was not attempted.

RESULTS AND DISCUSSION

Germination of Dry-stored Seeds. The germination trends of dry-stored seed are shown in Figure 1. The supply of watergrass seed was exhausted after 24 months. However, during this 2-year period, germination was low and ranged no higher than 4 percent. The germination of yellow bristlegrass was somewhat higher than that of green bristlegrass, ranging from 36 to 61 and from 22 to 41 percent, respectively, over the 33-month period. During the same period, germination of quackgrass seed varied from 33 to 53 percent. The

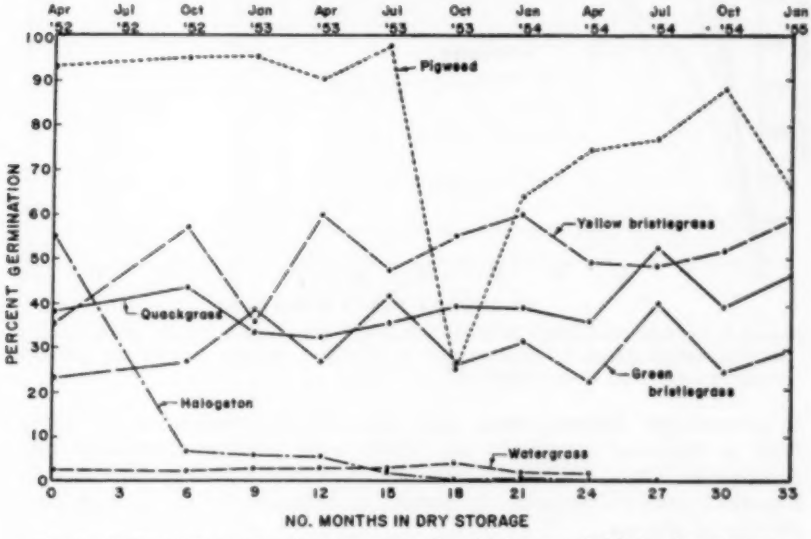

Figure 1. Percentage germination of seeds which were held in dry storage for periods ranging from 0 to 33 months.

greatest fluctuation occurred in the germination of pigweed seed. During the first 15 months, from 90 to 98 percent of the seeds sprouted while only 25 percent germinated after 18 months. However, during the last 12 months of the period, germination ranged between 63 and 88 percent. Crocker and Barton (3) reported a similar behavior or periodicity in the germination of pigweed seed. The germination of halogeton seeds (black) dropped sharply from an initial 55 to 7 percent after 6 months. No germination was obtained after 18 months of storage except 1 out of 200 seeds at the end of 24 months. The supply of seeds was exhausted after 27

months. These results indicate that black seeds of halogeton either enter dormancy or deteriorate quite rapidly even when held in dry storage.

Disintegration of Submerged Seeds. Some seeds germinated and/or disintegrated while submersed in fresh water. These were termed unsound seeds. The difference between the number of seeds initially placed in the bags and those present at removal time represented the loss shown as percentage unsound seed in Figure 2. Differences

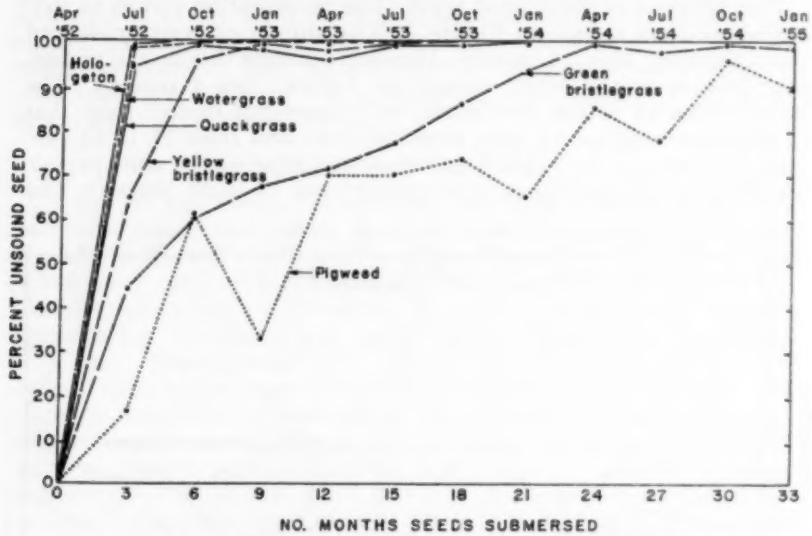

Figure 2. Average percentage of seeds which had germinated and/or disintegrated during submergence in fresh water at 12- and 48-inch depths for periods ranging from 0 to 33 months.

in percentage disintegration and percentage germination of seeds held at different depths in the water were neither consistent nor significant. Thus, the data presented in Table 1 and graphically in Figures 2 and 3 represent the means from both the 12- and 48-inch depths of storage.

The disintegration of watergrass seed was fairly rapid, 99 percent being unsound after 3 months of water storage. No seeds were sound after 18 months. Likewise, after 3 and 6 months, 95 and 99 percent of the quackgrass seeds had germinated and/or disintegrated. All had disintegrated after 27 months.

Green bristlegrass seeds appeared more resistant to the action of water than those of yellow bristlegrass. After 6 months, the unsound seed of green bristlegrass and yellow bristlegrass averaged 60 and 96 percent, respectively. The percentage of disintegrated green bristlegrass seeds increased gradually for 33 months, after which less than 1 percent of the seeds remained whole. No sound seeds of yellow bristlegrass were present after 27 months.

Over 99 percent of the black seeds of halogeton had germinated

Table 1. Average percentage of seeds that appeared sound and were placed in a germinator after 3 to 33 months of water storage and the percentage germination of these non-disintegrated seeds.

Months in water storage	Quackgrass		Green bristlegrass		Yellow bristlegrass		Watergrass		Pigweed		Halogeton (blackseed	
	Sound seeds	Germination	Sound seeds	Germination	Sound seeds	Germination	Sound seeds	Germination	Sound seeds	Germination	Sound seeds	Germination
	%	%	%	%	%	%	%	%	%	%	%	%
3	5	42	54	4	35	1	1	13	84	23	1	13
6	1	63	40	9	4	2	<1	25	39	73	<1	50
9	2	95	33	81	1	17	<1	50	67	29	1	25
12	4	42	29	65	1	88	0	0	29	81	<1	0
15	1	100	23	39	1	0	<1	0	30	67	<1	0
18	1	30	13	21	<1	0	0	0	26	60	0	0
21	<1	50	6	69	<1	50	0	0	35	50	<1	0
24	<1	17	1	50	<1	25	0	0	14	87	0	0
27	0	0	2	25	0	0	0	0	22	89	0	0
30	0	0	0	0	0	0	0	0	4	74	0	0
33	0	0	<1	0	0	0	0	0	10	80	0	0

and/or disintegrated after three months of water storage. After 12 months, all seeds had disintegrated.

The hard-coated pigweed seeds disintegrated less readily in water than those of the grasses and halogeton. Although the percentage fluctuated, the number of unsound seeds of pigweed tended to increase gradually over the 33-month period. At the end of this period, 90 percent of the seeds were no longer sound.

Germination of Sound Seeds After Submergence. When samples were removed for germination studies, the apparently normal, whole seeds present in the packets were termed sound, counted, and placed in the germinator. The quantity and percentage germination of these sound seeds are presented in Table 1.

Although the percentage of sound quackgrass, yellow bristlegrass, watergrass, and halogeton seeds was low after storage periods ranging from 3 to 24 months, the germination of these seeds fluctuated between 17 and 100, 0 and 88, 13 and 50, and 13 and 50 percent, respectively. The percentage of sound green bristlegrass seed decreased from 54 to less than 1 after 3 to 33 months of water storage. Germination ranged between 4 and 81 percent for 27 months, but no seeds germinated thereafter. The percentage sound seeds of pigweed decreased from 84 to as low as 4 during the 33-month storage period with germination fluctuating between 23 and 89 percent.

Total Percentage Germination of Seeds After Submergence. The total percentage germination, as presented graphically in Figure 3, was based on the initial number of seeds per sample and the number of seeds sprouting in the germinator.

Less than 1 percent of the watergrass seed germinated after storage in water for periods of 3 to 9 months. None germinated after 12 months.

The percentage germination of the yellow bristlegrass seed was lowered markedly after storage in water. One percent or less of the seeds germinated after periods ranging from 3 to 24 months. None sprouted after 27 months.

During the first 12 months, germination of the green bristlegrass seed fluctuated between 2 and 27 percent. Less than 10 percent sprouted after 15 months or more of submergence and none after 30 months.

Water storage decreased the percentage germination of the quackgrass seed also. Germination of these seeds averaged no more than 3 percent after being submersed for 3 months or longer. None sprouted after 27 months.

The percentage germination of the black seeds of halogeton decreased even more rapidly during water storage than during dry storage. Less than 1 percent of the seeds germinated after 3 months and none after 12 months.

In comparison, the percentage germination of submersed pigweed seed was lower than that of dry-stored seed. However, germination of these seeds ranged between 12 and 28 percent during the first 27 months of the water storage period. After 33 months, 9 percent of the seeds still sprouted.

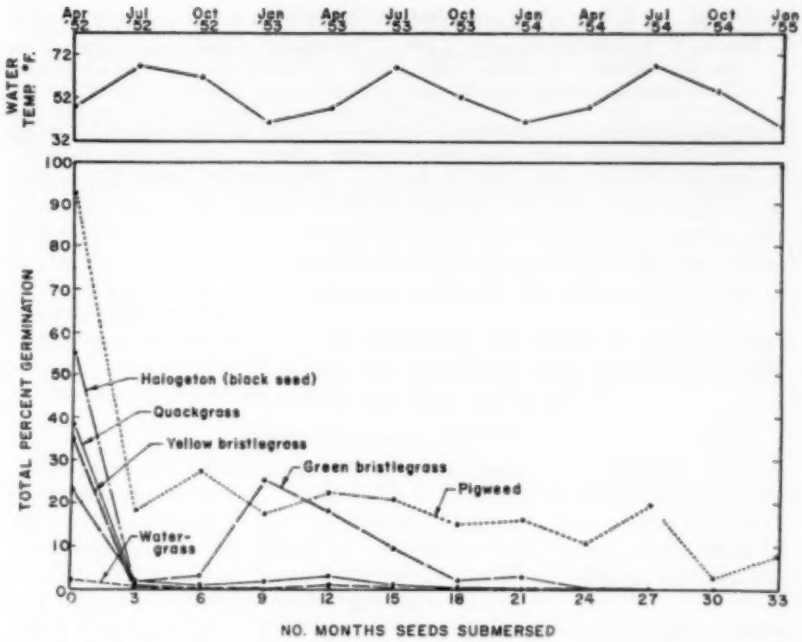

Figure 3. Temperature of the water and the average total percentage of seeds which germinated after submergence at 12- and 48-inch depths for periods ranging from 0 to 33 months.

Although exceptions may exist, studies completed to date indicate that the action of water may destroy the viability of seeds of the grassy weeds more readily than that of the hard-coated seeds of several broadleaved weeds including pigweed, Canada thistle, Russian knapweed, morning glory, and poverty weed. Nevertheless, a small percentage of the seeds of even grassy weeds may resist water action and maintain viability over an extended period.

Unlike previous tests (1, 2), little correlation between percentage germination and temperature of the water in the canal was exhibited.

SUMMARY

Seed samples of six different weeds were submersed at 12- and 48-inch depths in a canal and removed at 3-month intervals over a 33-month period for germination studies.

Less than 1 percent of the seeds of watergrass and black seeds of halogeton germinated after 3 months of water storage and none after 12 months. Also, 1 percent or less of the yellow bristlegrass and no more than 3 percent of the quackgrass seed sprouted after 3 months of submergence and none after 27 months. After 15 months or more of water storage, less than 10 percent of the green bristlegrass seed germinated and none after 30 months. After 33 months, 9 percent of the pigweed seed still sprouted.

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The Effects of 2,4–Dichlorophenoxyacetic Acid on Radicle Development and Stem Anatomy of Soybean[1]

M. Rojas-Garciduenas and Thor Kommedahl[2]

Sun (2) reported that pith cells in the hypocotyl of soybean (*Glycine max* (L.) Merr., variety Monroe) became meristematic and vascular strands developed in the pith after treatment with 2,4–dichlorophenoxyacetic acid (2,4–D). Later (3), he found a retardation in elongation of roots from treatment with 2,4–D. The pericycle produced a mass of dense meristematic tissue extending to the periphery of the root. Even non-conducting cells of the primary phloem of roots became meristematic.

The present study aimed to determine the effects of 2,4–D on the anatomy of soybean stems and on cell elongation and cell division. A brief summary of this work has been published (1).

Materials and Methods

Plants of the Blackhawk variety of soybean were sprayed with an alkanolamine salt of 2,4–D at 1 lb/A in the field when in the third trifoliate-leaf stage (6 to 8 inches tall). Fifteen days later, samples of stems were collected, fixed in formalin-aceto-alcohol, embedded in paraffin, sectioned at a thickness of 15μ with a rotating microtome, and stained with safranin-fast-green.

For studies of the effects on developing radicles, 5 soybean seeds were immersed in 2,4–D at 100 ppm for 1 hour, rinsed in water for 15 minutes, then allowed to germinate for 85 hours in petri plates. In comparison, 5 other seeds were immersed in water for 1 hour, then allowed to germinate for 85 hours.

Because seeds treated with 2,4–D grew more slowly, a third set of 5 seeds were immersed in water for 1 hour and allowed to germinate until radicles had attained lengths of those of treated seeds after 85 hours; this took 40 hours.

Results

Effect on radicle growth. Both hypocotyls and roots had differentiated when seeds not treated with 2,4–D were germinated for 85 hours. However, no such differentiation was found in radicles from seed treated with 2,4–D (and 85 hours old) or from seed not treated but germinated for only a 40-hour period.

Table 1 shows that the average cell length of radicles of treated seed was less than non-treated seed, 27.5μ and 47.7μ, respectively, when radicles of the same size were compared. The total number of cells was higher in treated, and older, radicles than in the non-treated ones. This may be expected because radicles compared were not of

[1]Contribution from Department of Plant Pathology and Botany, Institute of Agriculture, University of Minnesota, St. Paul 1, Minnesota. Paper No. 3786, Scientific Journal Series, Minnesota Agricultural Experiment Station. Portion of a thesis presented by the senior author to the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the M.S. degree.

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the same age; however they were of the same size. Thus it appears that 2,4–D inhibited elongation but not division of cells.

Although cells of treated radicles were shorter in all regions than cells of non-treated ones, the gradient of elongation of cells along the radicle was conserved as is evident by comparing lengths of cells in the four different regions (Table 1).

Table 1. The effect of 100 ppm 2,4–D on length and number of cells in soybean radicles of comparable sizes, after 85 hours germination of treated seeds and 40 hours of non-treated ones.

Distance from base of radicle at which cells were measured, in mm.	Average cell length per treatment, in microns[a]	
	Treated (85 hours old)	Non-treated (40 hours old)
1–3	18.7	27.6
3–6	21.2	42.7
6–9	25.0	46.7
9–11	29.9	52.7
12–13 (tip)	15.2	21.2
Average size	27.5	47.7
Total cell number[b]	407	251

[a]Each number represents average of 15 measurements from 5 radicles.
[b]Calculated by dividing the average cell length by length of radicle (except tip).

In Table 2 are compared radicles of comparable ages (85 hours), of treated and non-treated soybean seed. Treated radicles were only about one-fifth the size of radicles from non-treated seed after 85 hours germination. Cells in radicles of treated seeds averaged 27.5μ in length, and cells of non-treated seeds averaged 111.3μ. Also there were fewer cells in treated than non-treated radicles but the difference was not as great as expected considering the difference in length of radicles.

Therefore 2,4–D inhibited growth of the radicles and the effect was much greater in reducing cell elongation than cell division; cell elongation was reduced 75 per cent by 2,4–D but the rate of mitosis was reduced only 28 per cent. Thus data from both Tables 1 and 2 agree; however, from data in Table 2, it is possible to calculate the inhibition in rates of both cell elongation and division.

Effect on anatomy of plants in third-trifoliate-leaf stage. Fifteen days after spraying soybean plants with 2,4–D, stem sections were examined. Chloroplasts in cortical cells had disappeared, as observed also by Sun (2). Roots were initiated mainly from the endodermis and were composed also of cambium derivatives. Root initials eventually caused the epidermis to crack.

Phloem parenchyma cells proliferated and invaded the cortex, crowding cortical cells. Often these proliferations formed fan-shaped masses of parenchymatous tissue, in which very few phloem vessels were differentiated (Figure 1).

Discussion and Summary

Radicles of soybeans treated with 2,4–D had almost twice as many cells as non-treated ones of the same size. The treated soybeans required 45 hours more to equal the size of the untreated radicles. The cells in the radicles from treated plants were, on the average,

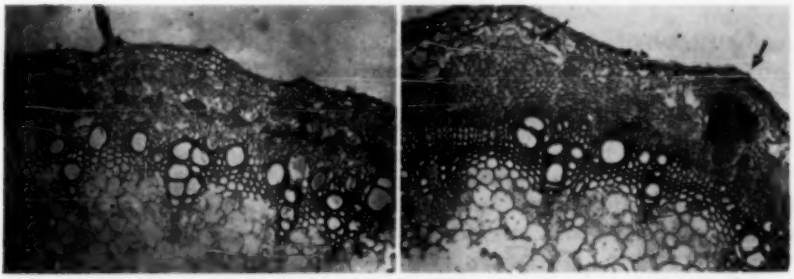

Figure 1. The figure on the left pictures the anatomy of a normal soybean stem of a plant 6 to 8 inches tall, in the third-trifoliate-leaf stage. The figure on the right shows the changes induced 15 days after spraying with 2,4–D. At the left in the right-hand picture, a fan-shaped mass of phloem parenchyma cells has invaded the cortex; a few phloem vessels have developed. Also, a root initial has pushed into the cortex; later stages show cracks in the epidermis from this pressure.

Table 2. The effect of 100 ppm 2,4–D on the length and number of cells in soybean radicles 85 hours of age but of different sizes.

Observation	Treated	Non-treated
Length of radicles, in mm[a]	12.2	65.8
Average cell length, in μ[b]	27.5	111.3
Number of cells per radicle[c]	407	565

[a]Based on averages of 5 radicles.
[b]Based on averages of 15 measurements and calculated from the average cell length in different regions into which radicle was divided.
[c]The numbers given are the calculated number of cells in a row from the base of the radicle to the distal end, not counting the tip, i.e. the average cell length divided by the radicle length less the tip.

58 per cent smaller than those radicles from non-treated plants. The rate of cell elongation was inhibited 75 per cent by 2,4–D and the rate of mitosis by 28 per cent. Thus the principal inhibitory effect was on cell elongation. Sun (3) also reported a retardation of root elongation but did not distinguish between cell elongation and cell division.

Soybean plants in the third trifoliate-leaf-stage were sprayed in the field with 2,4–D and the stems examined histologically. The major changes observed were: disappearance of chloroplasts from cortical cells, root initiation from the endodermis, and proliferation of phloem parenchyma that crowded, even crushed, cortical cells.

Proliferation in the phloem of roots from treatment with 2,4–D was found also by Sun (3). In addition he found that 2,4–D sprayed on seedlings of soybean, caused pith cells in the hypocotyl to proliferate (2). Using older plants, and examining the epicotyl of treated plants, the writers found that the phloem parenchyma, not the pith, proliferated.

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Control of Annual Bluegrass and Crabgrass in Turf with Fluorophenoxyacetic Acids

BURTON R. ANDERSON and STANLEY R. MCLANE[1]

IN contrast to the great development of chlorophenoxyacetic acids as herbicides, the fluorophenoxyacetic acids have received very little attention in weed control work, chiefly because they were difficult to synthesize. In addition until recently, they were not widely available. Thompson et al. (5) listed 2–fluorophenoxyacetic and 2–methyl–4–fluorophenoxyacetic acids as plant growth inhibitors. Crane and Blondeau (1) reported 4–fluorophenoxyacetic acid to be as effective as 4–chlorophenoxyacetic acid for inducing parthenocarpy in figs. A 100 ppm spray gave 88% fruit set with no foliar damage. Edgerton and Hoffman (2) stated that the same compound was moderately effective in delaying leaf abscission on apple trees and produced a 2,4–D-type formative effect on treated shoots. Weintraub et al. (6) showed with a bean leaf-area repression test that some of the fluorophenoxyacetic acids have a very high formative activity comparable to that of the most active chlorophenoxyacetic acids.

In this laboratory primary screening tests with various fluorophenoxyacetic acids and mixed fluoro-chloro-substituted acids showed marked differences among related compounds in their action on dicotyledonous seedlings. Some, such as 4–fluorophenoxyacetic and 2,4–difluorophenoxyacetic acids, damaged seedlings as much as 2,4–D while others including 2–chloro–4–fluorophenoxyacetic, 2,5–difluoro–4–chloro-phenoxyacetic and 2–chloro–4,6–difluorophenoxyacetic acids, were much less harmful. The individual fluoro-compounds differed much less in their action on monocot seedlings and were strikingly more effective than 2,4–D or 2,4,5–T. Treated monocotyledonous seedlings usually wilted, became stunted, and frequently were killed. Sometimes new, normal tiller shoots developed, effecting a recovery. Treatment of older plants generally produced little apparent vegetative response but resulted in appearance of malformed and partially or completely sterile inflorescences.

As the induction of sterility appeared to be an important effect of certain fluorophenoxyacetic acids, studies were undertaken first with millet *(Setaria italica)* as a greenhouse test plant because it is easy to grow and stands can be remarkably uniform. Subsequent experiments were carried out with annual bluegrass *(Poa annua)* and crabgrass *(Digitaria sanguinalis)* to determine if these grasses might be controlled in turf by destroying the annual seed crop.

METHODS

The portable precision small plot sprayer previously described (4) was employed to make spray applications. This device is basically

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a small battery powered compressor for activation of an atomizer. The test compounds were applied in 2–ethoxyethanol (cellosolve) at a rate of 4 cc of formulation per square yard. All solutions contained 0.5% Tween 20. Planting and handling procedures are described in the text with each particular test crop.

RESULTS AND DISCUSSION

Millet. Millet was sown directly into one-half-gallon glazed pots and the seedlings were thinned later to six per pot. They were grown in a greenhouse at 70° F. During the winter, day length was artificially supplemented to maintain a 14-hour day so as to prevent early, irregular anthesis. Five pots comprised a treatment sample. Mature seed was harvested and percentage yield reduction of treated samples was determined in relation to the weight of untreated controls. The compounds 4–fluoro–, 2,4–difluoro–, 2–methyl–4–fluoro, 2–chloro–4–fluoro–, 2,4,5–trifluoro–, 2,4,6–trifluoro–, 2,5–difluoro–4–chloro–, and 2,4–dichloro–5–fluorophenoxyacetic acid, applied at a rate of 1 lb/A, reduced seed yields from 80 to 100%. 4–Fluorophenoxyacetic acid was outstanding in its effect on the panicle (Figure 1–2). This compound was effective in producing sterility during only a relatively brief phase of growth. The most sensitive period was just after differentiation of the inflorescence, when it was 0.25 to 0.5 inch long and still deeply enclosed in the leaf sheaths.

During the most sensitive stage, spray application at rates as low as 0.025 lb/A occasionally reduced seed yields by 70%. Treatments with 1 lb/A during this period consistently reduced yields from 90 to 100%.

Because field plots of millet do not develop as uniformly as greenhouse material the sensitive stages of all plants do not coincide and induction of sterility has not been as complete as in greenhouse tests. Table 1 summarizes a field experiment in which 4–fluorophenoxyacetic and 2–methyl–4–fluorophenoxyacetic acids were applied to millet at three growth stages. The smallest amount of seed was produced in plants treated at the early reproductive stage.

Table 1. Percentage seed yield reduction resulting from treatments of field grown millet at different growth stages.

Growth stage	Application rate—lb/A					
	4-Fluorophenoxy-acetic acid			2-Methyl-4-fluoro-phenoxyacetic acid		
	0.25	0.5	1.0	0.25	0.5	1.0
Vegetative, 4 to 6 inches of growth	24	31	56	24	42	67
Early reproductive	82	76	86	32	44	72
Heads emerging	27	39	56	21	5	30

Table 2 summarizes results of a number of replicated greenhouse and field tests with several phenoxyacetic acids. The butyl esters of 2,4–D and 2,4,5–T, although potent herbicides for many dicotyledonous plants, were rather ineffective on millet at a rate at which the fluoro-compounds markedly reduced seed yield.

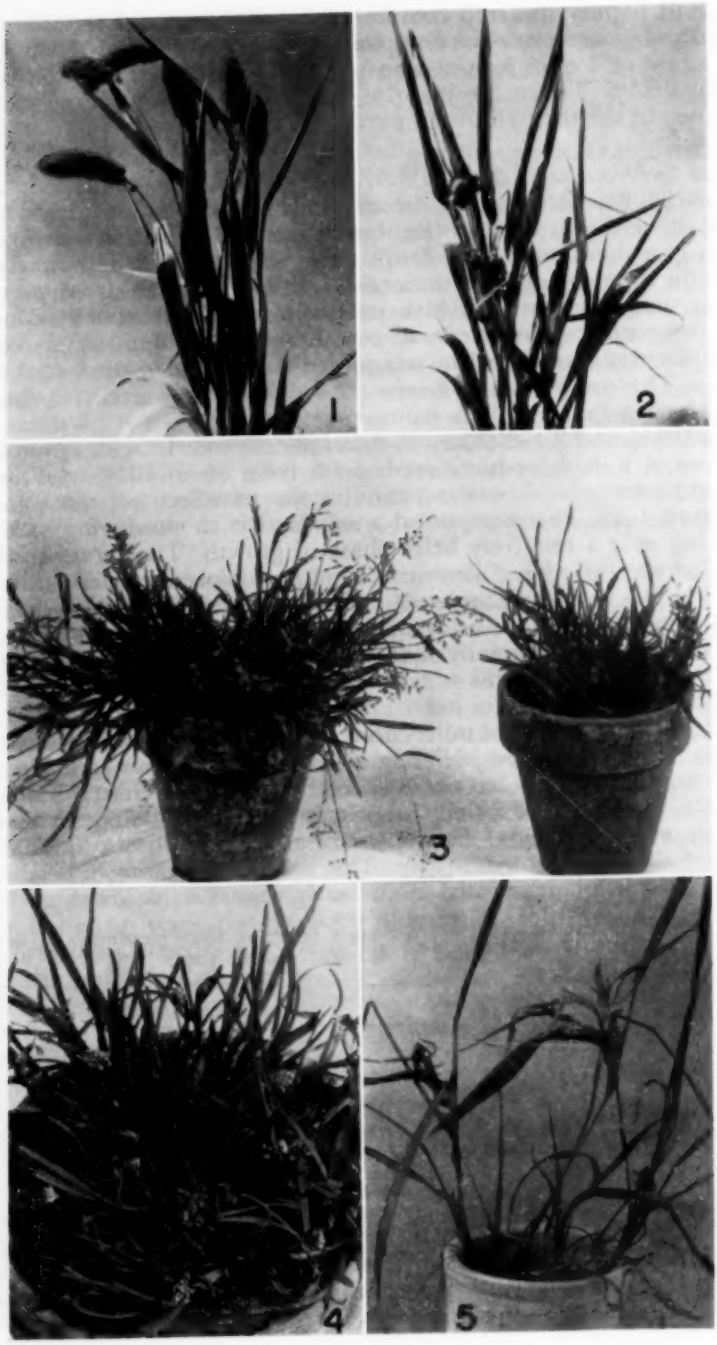
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Table 2. Seed yield expressed as percentage reduction compared with untreated control of field and greenhouse millet treated with various phenoxyacetic acids at an early reproductive stage of growth.

Phenoxyacetic acid	Application rates—lb/A										
	Field expts.					Greenhouse expts.					
	I		II		III	I			II		
	0.1	0.5	0.5	1.0	0.5	0.025	0.05	0.1	0.1	0.25	0.5
4-Fluorophenoxyacetic acid	34	61	54	68	54	68	79	83	68	72	89
2-Methyl-4-fluorophenoxyacetic acid	—	—	—	—	20	—	—	—	—	—	—
2,4-Difluorophenoxyacetic acid	—	—	41	76	23	—	—	—	—	—	—
2-Chloro-4-fluorophenoxyacetic acid	32	57	—	—	—	—	—	—	—	—	—
4-Chloro-2,5-difluorophenoxyacetic acid	2	49	—	—	—	—	—	—	—	—	—
2,4-D, butyl ester	—	—	—	—	3	—	—	—	—	—	—
2,4,5-T, butyl ester	—	—	—	—	5	—	—	—	—	—	—

Annual bluegrass. Engel and Aldrich (3) were the first to attempt control of annual bluegrass in turf by prevention of seed set. In their 3-year tests maleic hydrazide gave "good" seed-head suppression, but because of severe burning caused a net loss of bentgrass. The best compound in their tests was endothal which caused a net loss of annual bluegrass and clover; its seed-head suppression capacity was described as only "fair".

Considering the remarkable reduction of millet seed set without appreciable vegetative damage, it seemed likely that 4–fluorophenoxyacetic acid would be significantly superior to endothal and maleic hydrazide in the control of annual bluegrass in turf.

On October 3, 1955, week-old seedlings of annual bluegrass were transplanted into 4-inch clay pots and grown in a greenhouse at 60° F. After the plants became established, eight successive spray treatments of 4–fluorophenoxyacetic acid were applied on October 18 and every five days thereafter at a rate of 0.5 lb/A to a remaining group of untreated plants. By the time of the eighth treatment, November 21, untreated plants had formed a dense turf and a few panicles were emerging. Plants treated in the early stages were stunted, wilted and blue-green in color. A few weeks after these responses appeared some panicles began to emerge, most of them badly malformed (Figure 1–3). The main rachis and branches of the panicles failed to elongate, resulting in a compact mass of bunched spikelets (Figure 1–4). These distorted panicles were almost entirely sterile. Tiller shoots, newly differentiated at treatment time, later produced tubular leaves. Panicle emergence through these leaves was frequently completely suppressed. Panicles that did emerge were

Figure 1. The response of grasses to 4–fluorophenoxyacetic acid. (1.) Mature spikes of untreated millet. (2.) Spikes of millet treated with 4–fluorophenoxyacetic acid at 1.0 lb/A 30 days after treatment. (3.) Untreated annual bluegrass (left) and plants treated with 4–fluorophenoxyacetic acid at 0.5 lb/A (right). (4.) Treated annual bluegrass showing malformed panicles and tubular leaves. (5.) Crabgrass plants about 1 month after treatment with 4–fluorophenoxyacetic acid at 0.5 lb/A.

extremely malformed. A month or so after treatment these plants began to send out normally colored, vigorous tillers that produced normal, fertile panicles. Stunting and malformation were most severe in the first three treatments; older plants were less affected and produced seed at a nearly normal rate. These results indicated that annual bluegrass, like millet, passes through a developmental stage in which it is highly susceptible to 4–fluorophenoxyacetic acid.

After dissections of a number of annual bluegrass plants, it was found possible to predict the approximate stage of panicle differentiation from the gross appearance of a shoot. An annual bluegrass shoot bears 7 to 9 leaves above the prophyll. During development and emergence of the panicle, only the rachis and two subtending internodes elongate, raising the panicle and last two leaves above the basal leaf cluster. It was ascertained that in shoots with three, or at most four, visible leaves the panicles were 0.2 to 0.4 mm long and in a stage of differentiation comparable to that of millet at its most sensitive stage. At the first treatment stage in the experiment described above, only 16 such shoots were counted in the treatment sample, while several weeks later at least 80 distorted sterile heads appeared; this indicates that, unlike the situation in millet, bluegrass shoots with vegetative apices also were affected. The later stages were relatively undamaged showing that treatment after a period of panicle differentiation is ineffective. Development of the inflorescence is acropetal. A few panicles were distorted at the top but normal below, illustrating the abrupt reduction of sensitivity once differentiation has progressed beyond a certain stage.

On the basis of the first experiment another trial was made with the treatments confined to younger stages. Week-old seedlings were potted November 17 and samples were treated individually on November 28, December 2, 5, and 9 at rates of 0.25 and 0.5 lb/A. Results were similar to those of the first trial. Except at the last stage the 0.25 pound rate was as effective as the 0.5 pound rate.

In further experiments 2-week old seedlings of annual bluegrass from seed sown directly into pots containing soil were treated at 1.0 and 2.0 lb/A rates. Some plants were killed and from the survivors only a few malformed panicles developed at all. There was little recovery. Pre-emergence control with 4–fluorophenoxyacetic acid seems impractical as some seed germinated in the pots subsequent to the treatment and produced normal seedlings.

In other experiments, older annual bluegrass plants were clipped to simulate mowing and after a few days the plants were treated at rates of 1.0 and 2.0 lb/A. Development of new shoots was severely retarded and only a few produced even abortive panicles.

Sods of Kentucky bluegrass and bentgrass were placed in flats, transferred to the greenhouse, and treated at a 0.5 lb/A rate. The Kentucky bluegrass suffered only a temporary check in growth lasting about 2 weeks, whereas the bentgrass was checked somewhat more severely and took longer to recover.

Outdoor tests of 4–fluorophenoxyacetic acid were conducted in Wellesley, Massachusetts, on a nearly pure stand of annual blue-

grass. Three 6 by 3 foot plots were treated on April 28, 1956, two at a 0.5 pound and the third at 1.0 lb/A. On May 5, the treatment was repeated on one of the plots treated earlier at the 0.5 pound rate. During June the surrounding untreated area of annual bluegrass flowered prolifically. Within the treated area vegetative growth was less and no seed heads developed in those plots treated once at the 1.0 pound or twice at the 0.5 lb/A rates. In the plot treated only once at 0.5 pound a few scattered heads appear in early July.

On April 25, in Frederick, Maryland, plots of Kentucky bluegrass were treated at 0.5, 1.0 and 2.0 lb/A rates. Only the 2.0 pound rate caused damage, consisting of wilting and death of occasional plants. On May 5, in Wellesley, Massachusetts plots of Colonial bentgrass were treated at 0.5 and 1.0 lb/A rates. No damage was observed from either treatment.

4–Fluorophenoxyacetic acid applied at 0.5 to 1.0 lb/A appears to meet the requirements for successful control of annual bluegrass in turf, and to be worthy of field trials. It suppressed seed-head production and induced sterility without damaging vegetative parts of either annual bluegrass or the desirable basic grasses, Kentucky bluegrass and bentgrass. Annual bluegrass produces most of its seed heads during a short period in the spring so that it is possible to destroy most of the annual seed crop by one or two treatments applied 4 to 5 weeks prior to the flowering peak. Use of this compound on large turf areas to control annual bluegrass appears to be practicable. The annual bluegrass in treated turf would not be killed and thus avoid consequent opening of soil surface to invasion by other weeds. Golf greens receiving such treatment would thus remain smooth, free of open spots and seed heads, and continue to present a good putting surface for the season treated.

Crabgrass. Concurrent with the experiments on annual bluegrass, greenhouse trials were performed with crabgrass. Seed was sown in pots containing soil and placed in a greenhouse at about 70° F. Plants were treated at six stages of growth, the first being the one-leaf stage and the last when the panicle was 0.5 inch long. Application rates of 0.25 and 0.5 lb/A were used. Growth was severely checked at the 0.5 pound rate and badly malformed heads were produced (Figure 1–5). Treatment of all stages except the last produced malformation and sterility, showing that crabgrass is damaged by 4–fluorophenoxyacetic acid throughout the vegetative phase. After 6 to 8 weeks most plants recovered by sending out normal tillers. At the 0.25 pound rate there was less sterility, and recovery was more rapid than at the higher rate. In turf, the period of severe stunting may be sufficient to permit desirable species to suppress the crabgrass further by competition. Under northern field conditions it seems likely that treated seedlings would not recover in time to produce a seed crop before frost. From these results it appears that use of 4–fluorophenoxyacetic acid would be promising for control of crabgrass in turf.

SUMMARY

A number of fluorophenoxyacetic acids, including 4–fluoro–, 2,4–difluoro–, 2–methyl–4–fluoro, 2–chloro–4–fluoro–, 2,4,5–trifluoro–, 2,4,6–trifluoro–, 2,5–difluoro–4–chloro–, 2–chloro–4,6–difluoro–, and 2,4–dichloro–5–fluorophenoxyacetic acid induced sterility in grasses. The production of seed by millet in the greenhouse was reduced from 80 to 100% by application at a rate of 1.0 pound of 4–fluorophenoxyacetic acid per acre. The degree of susceptibility is related closely to stage of development when applied. At the most susceptible stage, 0.025 lb/A of this compound reduced seed yield by 70%.

Potted plants of annual bluegrass in the greenhouse were effectively sterilized from 4 to 6 weeks after treatment with 4–fluorophenoxyacetic acid at 0.5 lb/A. In a mowed lawn, plants failed to produce seed heads during the spring flowering peak after having been treated 5 weeks earlier with 0.5 to 1.0 lb/A. In the greenhouse crabgrass was severely checked from 6 to 8 weeks after treatment with 0.5 lb/A. Vegetative growth of Kentucky bluegrass and bentgrass in a lawn was not affected at a dosage of 1.0 lb/A. Effective control of annual bluegrass and crabgrass in fine turf by destruction of the seed crop therefore seems possible and worthy of field trial.

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BRIEF PAPERS

A Device for Seeding Greenhouse Flats

J. P. Crowder, Jr. and B. v. Schmeling[1]

The application of small samples of various weed seeds or seed mixtures to greenhouse flats for herbicidal studies is usually a manual operation. Various size flasks, beakers or test tubes are employed for the distribution of weed seeds to the soil surface of the flats. However, this method is time consuming and often results in uneven distribution of the seeds.

The need for a reliable method was apparent so that the device described herein was developed for applying small seeds to 14 x 10 x 3½ inch metal greenhouse flats. It is believed that this flat type is now widely used in herbicidal greenhouse studies.

The main feature of this device is a cone divider (Figure 1–A, No. 5) with tubes (Figure 1–A, No. 8) from the base of the cone to the distributing tube outlets (Figure 1–A, No. 10). These outlets are equipped with dispersion cross wires (Figure 1–A). The seeds are poured into the funnel (Figure 1–A, No. 1) which rests on the apex of the cone. By lifting the funnel the seeds fall on the cone

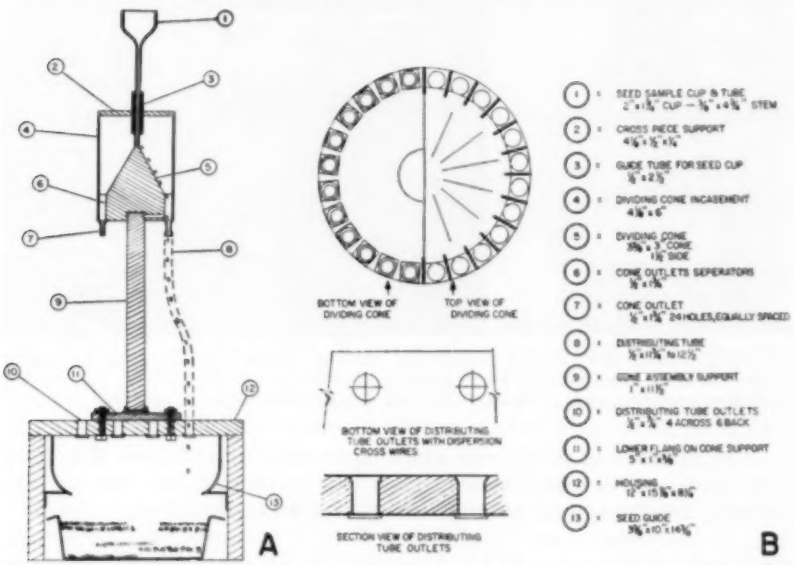

Figure 1. Construction details of the greenhouse flat seeding device. (A) Half section view. (B) Two views of the cone, distributing tube outlets and specifications for construction.

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divider and are then carried by gravity through the tubes to the soil surface. The dispersion cross wires produce a further scattering of the seeds to give a very uniform distribution over the seed flat. The half-section view and the position of the greenhouse flat are shown in Figure 1–A.

Twenty-four tubes and tube outlets were found to be sufficient for an even distribution of the seeds. Excellent uniformity of the seed pattern was obtained with rye grass, crabgrass, mustard, turnip, pigweed, lambsquarters, and various other weed and crop seeds as well as their mixtures when applied in amounts of ½ to 3 ml of seeds per flat.

The front view of the seeder is shown in Figure 2–A. Figure 2–B shows the front and the bottom view of the distributing tube outlets with the dispersion cross wires.

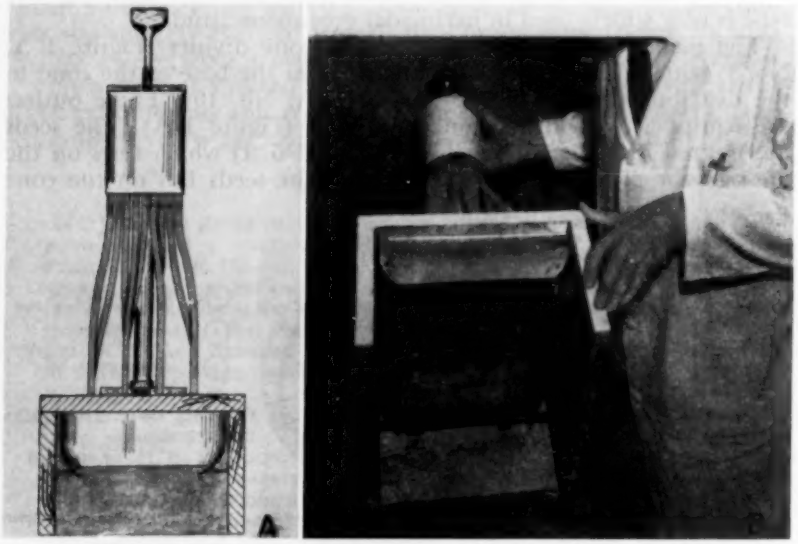

Figure 2. Front views of the greenhouse seeding device. (A) View of the seeder in operating position. (B) Photograph to show the relative size of the seeding device together with a view of the distributing tube outlets.

The number of dispersion cross wires may be changed if desired depending on the size of seeds used. It is visualized that the pattern of tube outlets can be arranged to give row applications.

Present Use of Herbicides on Highway Areas

JOHN W. ZUKEL and C. O. EDDY[1]

THE National Highway Program, recently approved, represents the largest peacetime construction program in history. The 41,000 mile network of interstate highways will be built on an average 300 foot right of way and will place over one million acres of land along the pavement subject to landscaping and maintenance.

Several highway landscape engineers have presented the following advantages resulting from use of herbicides along highway areas:

1. Increase highway safety by eliminating tall weeds. The presence of brush and tall weeds along the highway make driving hazardous by obscuring warning signs, traffic signals, and the view at curves, crossroads, and driveways.

2. Eliminate toxic plants such as poison ivy. These weeds result in lost time by highway maintenance workers and present a hazard to motorists using the shoulders and roadside parks. For example, the Connecticut Highway Department decreased lost-time accidents in 1954 among their maintenance force by 90% through the elimininations of poison ivy by the use of a selective herbicide program. The herbicide program also eliminates ragweed and other allergy-producing weeds from the right of way.

3. Keep water drainage areas free of weeds and brush which impede water flow.

4. Reduce weed population as a source of infestation to neighboring crops.

5. Elimination of weeds saves one or two mowings per year.

The Committee surveyed the states to secure information on the present use of herbicides. The results are summarized in Table 1.

The costs of mowing are reported in Table 2 for those states which reported these costs.

Highways are normally maintained for a distance of 10 feet from the pavement on each side of the road, or equivalent to 2.5 acres per mile. The 820,757 miles (Table 1) represents 2,051,892 acres. Approximately 60,000 miles or 7.3% of this mileage was treated one or more times with herbicides in 1955 at a chemical cost of $628,320.

The potential savings through use of herbicides may be illustrated by some cost analyses furnished by the state of Ohio. They reported a cost of $126.62 per mile per season for mowing areas not sprayed with 2,4–D and a cost of $108.17 per mile for both mowing and cost of chemical treatment, for a savings of $18.45 per mile by use of an herbicide.

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[1]Secretary and Chairman, respectively, Chemicals Subcommittee, Committee on Roadside Construction and Maintenance, American Roadbuilders' Association. Address: Naugatuck Chemical Division, U. S. Rubber Company, Bethany, Connecticut; and Niagara Chemical Division, Food Machinery and Chemical Corp., Middleport, New York, respectively.

Table 1. Cost of herbicides used along highways in 1955.

State[a]	Miles of road in state system	Total cost of herbicides used in 1955	Type of herbicide used[b]
Alabama	16,286	$ None	
Arizona	3,975	15,000	
California	14,000	88,675	Sodium borate-chlorate
Colorado	15,693	12,510	Sodium borate-chlorate
Connecticut	3,000	30,200	2,4-D, 2,4,5-T, dalapon
Delaware	3,997	None	
Florida	12,950	5,550	Monuron
Iowa	9,686	21,376	2,4-D, 2,4,5-T
Idaho	4,708	22,775	2,4-D, 2,4,5-T
Illinois	12,954	34,500	2,4-D, 2,4,5-T
Kansas	10,730	47,902	2,4-D, sodium chlorate
Kentucky	18,821	7,665	Dalapon, ammonium sulfamate
Louisiana	15,146	19,000	Ammonium sulfamate, TCA
Maine	13,833	3,200	Ammonium sulfamate, 2,4-D, 2,4,5-T
Maryland	4,625	None	
Massachusetts	7,606	25,700	2,4-D, 2,4,5-T
Michigan	103,085	24,717	2,4-D, 2,4,5-T
Minnesota	24,481	25,276	2,4-D, 2,4,5-T
Mississippi	15,953	None	
Missouri	22,505	40,143	2,4-D, 2,4,5-T, TCA
Montana	19,838	11,400	2,4-D, 2,4,5-T, sodium chlorate
Nebraska	18,572	7,793	2,4-D, 2,4,5-T, sodium chlorate
Nevada	3,909	None	
New Hampshire	4,026	675	2,4-D, 2,4,5-T
New Jersey	4,005	2,000	2,4-D, 2,4,5-T
New Mexico	18,748	599	Monuron
New York	12,964	5,000–7,500	2,4-D, 2,4,5-T, dalapon, monuron
North Carolina	89,901	Under 1,000	
North Dakota	6,606	None	
Ohio	27,935	73,332	2,4-D, 2,4,5-T
Oklahoma	20,714	None	
Oregon	7,427	37,176	2,4-D, 2,4,5-T, sodium borate-chlorate
Pennsylvania	41,207	13,075	2,4-D, 2,4,5-T
Rhode Island	956	1,148	2,4-D, 2,4,5-T, ammonium sulfamate
South Carolina	24,228	None	
South Dakota	6,310	18,186	2,4-D, sodium borate, monuron
Tennessee	14,787	None	
Texas	52,000	None	
Virginia	49,931	21,527	2,4-D, 2,4,5-T, dalapon
Washington	5,785	2,500–5,000	2,4-D, 2,4,5-T. monuron
West Virginia	31,299	None	
Wisconsin	22,630	3,721	2,4-D, 2,4,5-T
Wyoming	4,945	None	
Total	820,757	$628,320	

[a]No reports received from Arkansas, Georgia, Indiana, Utah, Vermont.
[b]Chemicals used in minor quantities in each state are not listed. Cost of chemical does not include application costs.

Table 2. Cost of mowing roadside areas during 1955.[b]

State	Average cost per acre per mowing	Average cost per acre per season
Colorado	$ ——	$ 1.75
Connecticut	——	300.00
Florida	9.00	18.00
Illinois	12.00	40.00
Louisiana	1.75 to 3.0	——
Massachusetts	12.00	36.00
Minnesota	——	13.60
Montana	3.37	6.75
New Mexico	5.12[a]	——
Ohio	——	50.64[a]
Oregon	4.35	8.70
Pennsylvania	30.00	90.00
Rhode Island	14.00	120.00
Texas	5.00	15.00
Virginia	7.25	14.50
Wyoming	4.44	11.10

[a]Cost reported per mile and converted to acres. (1 mile equals 2.5 acres).
[b]The following total mowing costs for 1955 were reported: Mississippi—$679,916, Nebraska—$500,000, South Dakota—$488,544.

Promising chemicals which are of potential use but which require development are:

1. Pre-emergence chemicals to protect new plantings during their period of establishment from weed competition.
2. Substitute soil sterilants for mechanical means of producing fire breaks along highways.
3. Growth inhibitors such as maleic hydrazide to reduce frequency of mowings and to inhibit terminal tree growth under utility lines.

The 41,000 mile highway system will produce a 1,000,000 acre park which must be maintained. This high quality road will require a correspondingly high quality maintenance.

The highway departments will be hard pressed in finding the manpower to operate equipment to maintain present and proposed highways. The extended use of herbicides, commonly used in other fields, can be adapted to highways to reduce costs.

The regular federal aid program, administered by the Bureau of Public Roads, which is distinct from the new Federal Aid Highway Bill, allocates 2½ billion dollars per year to the states. A provision in this program provides 1½ per cent of this fund on a yearly basis for research on highway problems. This research fund has in the past been used primarily for physical research on highway materials. There is a recent trend to the use of these funds for research, which might include evaluation of chemicals to reduce maintenance costs. Such research projects are initiated through the materials or research engineer of each state highway department.

Herbicides have demonstrated a saving in maintenance on present highways. Further research, education, and development should expand use of these chemicals to secure safe, beautiful and healthful highway areas while reducing maintenance costs and promoting roadside conservation practices.

A Rapid Laboratory Method of Screening Herbicides Against Aquatic Plants

W. S. HARDCASTLE[1]

IN the recent past, the various plant species which are lumped together in the general class of aquatics have received considerable attention from workers in the field of weed control because of their importance in affecting water usage in irrigation, water reservoirs, transportation, and recreational facilities.

In attacking these plants with herbicides, a third, and very important dimension is introduced into weed control: in addition to length and width of the treated area, depth must be taken into consideration. In aquatic control work, the treated area is a vertical column rather than a plane surface, and application per unit must be considered in terms of acre feet of water[2] or other cubic measure. This factor increases the total dosage in proportion to the depth,[3] as well as in relation to the total size of the area to be treated.

Field screening of herbicides against submerged aquatic plants and emergent aquatics which do not respond readily to normal spray treatment or grow adjacent to sensitive crop plants is difficult due to the diffusion of materials from the treated area and the long distances which it is often necessary to travel before finding stands of a given species which are suitable for test work.

With the extensive aquatic flora extant in Louisiana a method of rapidly screening a number of herbicides against a number of weed species was mandatory to the expansion of the extensive control program of the Louisiana Wild Life and Fisheries Commission now in progress on water hyacinth *(Eichhornia crassipes* (Mart.) Solms.) in the inland waters of the state.

A method which has worked very effectively with such plants as alligator weed *(Alternanthera philoxeroides* (Mart.) Griseb.), Brazilian water weed *(Anacharis densa* (Planchon) Marie-Vict.), parrot feather *(Myriophyllum brasiliense* Comb.), and a colonial blue-green alga (*Aphanocapsa sp.* Naegeli) is described below.

Approximately 175 gm of soil are placed in a wide mouth Mason type fruit jar, 1 qt size, and 500 ml of water are poured into the jar. A line is scribed on the side to mark the water level to facilitate bringing the water back to volume to replace loss by evaporation and transpiration.

Plants collected in the field are transported to the laboratory in water and are prepared for rooting by selecting terminal sections approximately 8 inches in length which are cut under water and placed in the fruit jars, one per jar, without exposing the vascular system to air. These plants are pushed into the soil at the bottom of the jars and the water is swirled slightly to seat them. They are

[1]Biologist, Noxious Weed Control Research Project, Louisiana Wild Life and Fisheries Commission, Baton Rouge, Louisiana.

[2]1 acre foot = 43,560 cuft of water.

[3]2.7 lb/A ft = 1ppmw (approx).

grown until well rooted, a period of approximately 2 weeks, and then the test herbicide is introduced.

At the time of treatment, appropriate concentrations of the test material are made and used to replace the water in which the plants are growing, 500 ml of treated water being used in each jar. Four jars per plant species are treated with each test concentration of each herbicide. Appropriate checks are prepared by draining and refilling jars with untreated water.

The observed effects of a chemical concentration are rated on a 0–10 rating scale with 0 indicating no effect and 10 complete kill. Occasionally with a plant such as Aphanocapsa in which the breakdown of the gelatinous matrix is an important factor, a 10+ rating is included to indicate this special effect. The results of a screening test against Brazilian water weed are shown in Table 1.

Table 1. Results of screening test against Brazilian water weed.

Herbicide	Concentration ppmv or ppmw	Activity rating[a,b]	
		After 14 days	After 21 days
3-(*p*-chlorophenyl)-1,1-dimethylurea	5	0.0	0.0
	10	0.0	0.0
	100	0.0	0.0
3-(3,4-dichlorophenyl)-1,1-dimethylurea	5	0.7	1.0
	10	0.0	0.7
	100	4.3	8.0
Dehydroabietylamine acetate	1	5.3	5.5
	5	9.5	10.0
	10	10.0	10.0
Isopropyl N-(3-chlorophenyl) carbamate	5	0.0	0.0
	10	0.0	0.0
	100	10.0	10.0

[a]Rating scale: 0 = no effect; 10 = complete kill.
[b]All ratings average of four replications.

An alternate method which avoids draining and refilling and the resultant turbidity, is the use of 450 ml of water for rooting and the addition of 50 ml of appropriate stock solution to give the desired concentration of herbicide. Although this method results in less turbidity, it is very difficult to bring the rooting water to exactly 450 ml due to the variation of water absorption of the soil component.

The time of exposure necessary for effective control of a given aquatic species is an important factor, especially in flowing water. The above method is easily adapted to obtaining an indication of this time factor by replacing the treated water with untreated water at varying intervals.

The Effect of Isopropyl N–(3–Chlorophenyl)Carbamate on the Carbohydrate Content of Soybean Plants[1]

JOHN A. MEADE[2]

THE herbicide isopropyl N–(3–chlorophenyl)carbamate (CIPC) has been found to be effective in controlling annual grasses when applied as a pre-emergence treatment. This herbicide is also very effective in controlling chickweed (1, 9, 12) and grasses in dormant alfalfa (11).

It has been shown that IPC (3), urethane, and ethylphenyl carbamate cause disruption of mitosis in root tip cells (6, 7). Tomizawa and Koike (10) have shown that IPC has an effect on several enzymes and on the phosphate and sugar levels in plants.

Work published earlier by this author (8) indicates that CIPC causes an increase of reducing sugars, invert sugars, and total sugars of corn plants. A similar study was undertaken with soybeans to determine if CIPC is truly a specific herbicide for grasses.

Soybean seeds were planted in the greenhouse and the soil surface sprayed with CIPC in acetone. Rates of 4 and 8 lb/A were used. Initial watering was from above to insure movement of CIPC into the soil. At the time of harvest 26 days after planting, the soybeans were in the 2nd trifoliolate leaf stage.

Of the 80 plants in each flat, 16 were harvested from the 8 pound treatment and 8 from the 4 and 0 pound treatments. The larger number was necessary for the 8 pound treatment because of severe stunting. The plants were excised at the soil surface, separated into stems, leaves, and cotyledons, and extracted with 80% ethanol in a soxhlet apparatus. An aliquot of the alcoholic extract was evaporated to dryness, dissolved in water, and cleared with neutral lead acetate. Reducing substances were then determined by the ceric sulfate method as outlined by Hassid (4, 5) and modified by Barr (2). Total sugars were determined after inversion with HCL.

The 4 pound rate of CIPC caused no significant changes in any of the carbohydrate fractions as is shown in Table 1. The 8 pound rate

Table 1. The effect of CIPC as a pre-emergence treatment on the levels of reducing, invert, and total sugars of soybean plants grown in a greenhouse. Figures are milligrams per gram of fresh weight.

CIPC appl. lb/A	Reducing sugars			Invert sugars leaves	Total sugars leaves
	Leaves	Stems	Cot.		
0	4.59	3.92	3.73	0.21	4.80
4	3.69	2.54	4.29	0.55	4.24
8	6.22	6.26	3.28	2.89	9.11
5% LSD	1.24	2.08	NS	1.70	3.06

[1]Published with the approval of the Director of the Maryland Agricultural Experiment Station as Scientific Article No. A598, Contribution No. 2773.

[2]Instructor, Agronomy Department, University of Maryland Agri. Exp. Sta., College Park, Maryland.

caused an increase of 35% in reducing sugars of the treated leaves over the check. This rate also caused a 60% increase in the reducing sugars of the stems.

The invert sugars of the leaves that had received the 8 pound treatment were 14 times greater than the untreated check. Total sugars of the treated leaves showed an increase of 90% over the check.

The herbicide CIPC apparently increases the amounts of reducing and non-reducing sugars in soybean plants. This would indicate that in respect to these carbohydrate fractions CIPC has the same effect on soybeans as on corn.

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Dalmatian Toadflax—A Possible Rival of Goatweed as a Serious Range Weed

A. W. LANGE[1]

GOATWEED, *Hypericum perforatum,* has long been considered among the most serious of weeds attacking the western ranges. It not only dominates large areas of range land, thus reducing the kind and amount of native forage, but it has poisonous properties as well. Livestockmen had good reason to bless the Chrysolina family of beetles and the men who pioneered their introduction into the goatweed infested range county. They are doing a marvelous job of reducing this weed.

In Eastern Washington and Northern Idaho some livestockmen and weedmen are beginning to wonder if the territory being reclaimed by the beetles is not being prepared for another invasion. This time by a weed having many of the growth characteristics of goatweed but with even greater potential as regards rate of spread and adaptability to conditions unsuited to goatweed. The weed in question is Dalmatian toadflax, *Linaria Dalmatica.*

Dalmatian toadflax is undoubtedly an escaped ornamental. Some seed catalogs used to include it among their perennials. It is moderately deep rooted and reproduces from underground roots and from seeds borne in great abundance on long racemes terminating on stems 12 inches to 3 feet in height. Roots have been dug to a distance of 12 feet from the parent plant with buds ranging from 3 inches to 3 feet along the root system. Vertical roots extend several feet into the ground. It tillers in the fall as does goatweed. These tillers may grow up the following spring and produce seed or they may fail and others be produced which perform the seeding function. Flowers are a beautiful yellow, tinged with orange and the solidly covered hillsides are a beautiful sight indeed. Flowering begins in June and may last until late fall but most of the seed is produced between June and early September.

Old established plants form large crowns and may develop as many as 12 to 15 stems at ground level. A plant of this size may produce as many as 400,000 seeds. One incomplete study gave a germination rate of 25% to 30%. Some seed will germinate in the same season as produced. Leaves are smooth and glossy, similar to that of the onion, making them somewhat difficult to wet.

As compared to goatweed, which was first noted in the United States in 1793 and on the Pacific Coast in 1899,[2] Dalmatian toadflax is a newcomer, having been brought to the attention of personnel at the State College of Washington for the first time in 1926. It was submitted for identification by Aubrey L. White, a public-spirited citizen engaged in the development of a park area along the Spokane River northwest of Spokane. Part of this area is adjacent to Fair-

[1]Supervisor, Spokane County Weed Control, Courthouse, Spokane, Washington.
[2]Harris, Grant. Station Paper No. 26, Northern Rocky Mountain Forest and Range Experiment Station, 1951.

mount Cemetery where the original infestation apparently started. Many of the scattered infestations in eastern Washington have started in cemeteries.

The park people welcomed this newcomer for the beautiful wild flower that it is. It was not long before their entire park was not only a mass of wild beauty but also an incubator from which the infestation spread throughout the northern and eastern parts of the county and on into Idaho and the northern counties of eastern Washington. The "pothole" and pasture areas south of Spokane are now becoming heavily infested. The plant seems to have exceptional ability to establish a vanguard far from the centers of infestation. It is now reported in every county in eastern Washington and some counties in the coastal regions.

The territory thus far mentioned is predominantly the Ponderosa pine type. There can be little doubt that this environment is particularly favorable to the toadflax. There is, however, abundant reason to believe that the plant will become established under conditions of heavy competition and remain there in a subdued role until the competition is reduced or destroyed. When this happens Dalmatian toadflax quickly avails itself of the chance to become a pest.

Producers of grass seed have already experienced trouble. The heavy applications of fertilizer necessary for grass seed production favors tremendous growth of the toadflax. In several fields the weed has persisted in summerfallow and appeared in the following wheat crop. Thin stands of alfalfa also provide a good place for it to grow. These few examples do not establish Dalmatian toadflax as a cropland weed of high importance but they do justify uneasiness in that direction. Since all of the cases mentioned resulted from seed brought to the infested area from a distance by unknown means, one can only guess what the result of carelessness in the control of seeding might be.

In addition to the infestations already mentioned in Washington and Idaho, there are some sizable infestations in Canada both in the prairie provinces and in the intermountain region. Idaho has moved quickly to control most of her small infestations but the great river valleys along the Salmon and Clearwater still are threatened. A small infestation has also been reported from the John Day River Valley in Oregon. Most of these areas are the identical areas now being liberated from goatweed by the Chrysolina beetle. In Spokane County, Dalmatian toadflax has already spread into goatweed infested territory and greatly outdistanced that weed in the competition for new territory. It has also made its way into strong stands of native cover that have not been subjected to grazing for many years. These infestations grow slowly but steadily. Apparently it is not a poisonous plant but livestock shun it almost without exception. One report of sheep and goats eating the flowers has been recorded this year.

Borax materials have given the most consistent chemical control. Propylene glycol butyl ether ester of 2,4–D (2,4–dichlorophenoxy-

acetic acid) has given the best results of any 2,4–D material but these results are not consistent. The Washington State Agricultural Experiment Station is testing other materials some of which appear to be very effective but prohibitive at present prices.

At present the main hope lies in biological control. There is no assurance that this is possible. Certainly the involvement with economic species is ever present. The United States Department of Agriculture has approved a study to determine if biological control possibilities exist. Congress has appropriated the necessary funds. Reports from the foreign field indicate some work has been done.

Spokane County contains approximately 50,000 acres of the 200,000 acres of goatweed reported in the state of Washington and affords ample opportunity for study of the weed under a variety of conditions. The ability of the weed to thrive in great areas of the intermountain and coastal regions is unquestioned. Spokane County also has about 40 sections of land heavily infested with Dalmatian toadflax with starts in every part of the county and the adjoining region. This spread has been accomplished in less than half the time required for goatweed to make a comparable spread. It grows anywhere goatweed will grow and has spread rapidly into areas in which goatweed made no progress. It has already demonstrated more cropland potential than goatweed. Should it live up to its initial threat it would appear that there is little in weed control at this time that can save large areas of the western range from a problem much more difficult than that created by goattweed. It is not too early to subject this newcomer to the best we have in prevention. Publicity, control of the vanguard, and a search for more efficient means of control for established areas of infestation on low-value lands with emphasis on biological control would seem to be in order at this time.

Report of the Terminology Committee—Weed Society of America

I. Introduction.

One of the most acute problems in weed control terminology is the need for the development and adoption of common names for herbicides. This problem is not limited to the field of weed control alone. Every scientific field which envelops the use of agricultural chemicals is confronted with the adoption of common names for chemicals used in agriculture.

The Committee believes that during the discovery, development, and use of herbicides at least two distinct nomenclature phases must be recognized in the selection of a designation to be used for a herbicidal chemical. It is difficult if not impossible to coin common names for herbicidal chemicals until they have reached the commercial development stage. However, the Committee recognizes that an acute need exists for abbreviated designations for herbicidal chemicals while they are in the research and development stages prior to the time they become commercially available.

The objectives of the Committee which have been designed to meet these needs are: (1) to serve as a group to coordinate the terminology in the field of weed control, including the selection of common names for herbicides and weeds, and (2) to review, revise, and develop standardized terms, abbreviations, and definitions used in the field of weed control.

A committee known as the American Standards Association Sectional Committee on Common Names For Pest Control Chemicals, K 62 (ASA–K62) has been organized for the purpose of adopting and standardizing common names for chemicals used as herbicides, insecticides, fungicides, rodenticides, nematicides, defoliants, and plant regulators. The American Standards Association (ASA) is also a member of the International Standards Organization (ISO) and the ASA Committee, K 62 will work with foreign countries through ISO in its efforts to standardize common names for agricultural chemicals throughout the world.

The Weed Society of America is a member of ASA–K 62, which is composed of scientific societies and all other organizations interested in agricultural chemical nomenclature. The Terminology Committee of WSA is represented on the ASA–K 62 Committee by the WSA Terminology Committee chairman and two alternates. We have participated in all the meetings of ASA–K 62 relating to herbicide terminology and aided in the development of the procedure for developing common names for pest control chemicals which was published in Weeds 4:278–284 July 1956.

Sponsors of common names for herbicidal chemicals should prepare ten copies of a "Statement" in accordance with the procedures established by ASA–K 62 and published in Weeds, and forward the Statement to the Chairman of the WSA Terminology Committee for action by the Committee. If the common name proposed by the

Sponsor is accepted by the Terminology Committee of WSA, the Committee will recommend that the Sponsor prepare copies of the Statement for submittal to the American Standards Association Sectional Committee on Common Names for Pest Control Chemicals, K 62 for final disposition.

II. CHEMICAL NOMENCLATURE, ABBREVIATIONS, AND DEFINITIONS.

A. Suggested terminology guides for authors to follow in preparing manuscripts for publication in WEEDS *or any other publication of WSA.*

The editorial board will not approve manuscripts for publication in any publication of WSA in which trade names, code names, code numbers, or abbreviated names are used without identifying the active ingredient in the herbicide. The first time a herbicide is mentioned in a manuscript, research report, abstract, or other publication, the full chemical name of the herbicide should be given followed by the accepted common name or designation. Herbicides for which designations have not been developed should be designated by their full chemical names.

The exact derivative of compounds should be used. For example, in the body of manuscripts use, diethanolamine salt of 2,4–D, isopropyl ester of 2,4–D, butoxyethanol ester of 2,4–D; while for tabular presentation use, 2,4–D, sodium salt; 2,4–D, butyl ester etc. Avoid the use of sodium 2,4–D; 2,4–D sodium; amine 2,4–D; 2,4–D amine; LV ester of 2,4–D; 2,4–D ester, etc.

Rates of application should always be stated in terms of the acid equivalent when applicable and when not applicable, in terms of the active ingredient.

Designations for chemical compounds involving a combination of numbers and letters should be written with capital letters without spacing or periods. The numbers should be separated by commas and the numbers and letters should be separated by a dash (–). For example: 2,4–D, MCPA, 2,3,6–TBA, 4–(2,4–DB), 4–(4–CPB). In writing accepted common names, lower case letters should be used. For example: monuron, diuron, dalapon.

In acknowledging the source of experimental compounds it is suggested this be done in a footnote rather than by the use of trade names in the body of manuscripts. For example: "In these studies three compounds, 2,4–D,[1] MCPA,[1] and 2,4,5–T[1] were applied at three rates of application and at three stages of growth."

D. Definitions of terms used in weed control.

Term	*Definition*
Annual.	A plant that completes its life cycle from seed in one year.
Band application.	An application of spray or dust to a continuous restricted area such as in or along a crop row rather than over the entire field area.

[1]The authors wish to acknowledge the cooperation of the ABC Chemical Company, Hometown, Pa. in supplying the compounds for these investigations.

B. *Nomenclature for chemicals used as herbicides.*

Chemical name	Designations accepted for use in all publications of WSA
2,4-dichlorophenoxyacetic acid	2,4-D
2-methyl-4-chlorophenoxyacetic acid	MCPA
2,4,5-trichlorophenoxyacetic acid	2,4,5-T
3,4-dichlorophenoxyacetic acid	3,4-DA
4-chlorophenoxyacetic acid	4-CPA
2-(2,4-dichlorophenoxy)propionic acid	2-(2,4-DP)
2-(2-methyl-4-chlorophenoxy)propionic acid	2-(MCPP)
2-(2,4,5-trichlorophenoxy)propionic acid	silvex (sĭl′vĕks)
2-(3,4-dichlorophenoxy)propionic acid	2-(3,4-DP)
2-(4-chlorophenoxy)propionic acid	2-(4-CPP)
4-(2,4-dichlorophenoxy)butyric acid	4-(2,4-DB)
4-(2-methyl-4-chlorophenoxy)butyric acid	4-(MCPB)
4-(2,4,5-trichlorophenoxy)butyric acid	4-(2,4,5-TB)
4-(3,4-dichlorophenoxy)butyric acid	4-(3,4-DB)
4-(4-chlorophenoxy)butyric acid	4-(4-CPB)
sodium 2,4-dichlorophenoxyethyl sulfate	sesone[a] (sĕs′ōn)
2,4,5-trichlorophenoxyethyl sulfate	2,4,5-TES
2-methyl-4-chlorophenoxyethyl sulfate	MCPES
2,4-dichlorophenoxyethyl benzoate	2,4-DEB
trichloroacetic acid	TCA
2,2-dichloropropionic acid	dalapon (dăl′ăpŏn)
2,2,3-trichloropropionic acid	2,2,3-TPA
dichloral urea	DCU
2-chloro-N,N-diallylacetamide	CDAA
2-chloro-N,N-diethylacetamide	CDEA
isopropyl *N*-phenylcarbamate	IPC
isopropyl *N*-(3-chlorophenyl)carbamate	CIPC
sec-butyl *N*-(3-chlorophenyl)carbamate	BCPC
2-chloroallyl diethyldithiocarbamate	CDEC
3-phenyl-1,1-dimethylurea	fenuron (fĕn′ ū rŏn)
3-(*p*-chlorophenyl)-1,1-dimethylurea	monuron (mŏn′ ū rŏn)
3-(3,4-dichlorophenyl)-1,1-dimethylurea	diuron (dī′ ū rŏn)
1-*n*-butyl-3-(3,4-dichlorophenyl)-1-methylurea	neburon (nĕb′ ū rŏn)
pentachlorophenol	PCP
4,6-dinitro *o* secondary butylphenol	DNBP
4,6-dinitro *o* secondary amylphenol	DNAP
3,5-dinitro *o* cresol	DNC
2,3,6-trichlorobenzoic acid	2,3,6-TBA[b]
2,3,5,6-tetrachlorobenzoic acid	2,3,5,6-TBA[b]
N-1-naphthylphthalamic acid	NPA
3,6-endoxohexahydrophthallic acid	endothal (ĕn′ dō thăl)
phenylmercuric acetate	PMA
potassium cyanate	KOCN
hexachloroacetone	HCA
isopropyl xanthic acid	IPX
maleic hydrazide	MH
trichlorobenzene	TCB[b]
orthodichlorobenzene	DCB
2-chloro-4,6-bis(diethylamino)-*s*-triazine	CDT
3-amino-1,2,4-triazole	amitrol (ăm′ ĭ trŏl′)
octochlorocyclohexenone	OCH
ethyl xanthogen disulfide	EXD
monomethylarsonic acid	MAA
2-(2,4,5-trichlorophenoxy)ethyl 2,2-dichloropropionate	erbon (ŭr′ bŏn)
polychlorobenzoic acid	PBA[b]
2-chloroethyl N-(3-chlorophenyl)carbamate	CEPC
2-(1-chloropropyl)N-(3-chlorophenyl)carbamate	CPPC
ethyl N, N-di-*n*-propylthiolcarbamate	EPTC
ethyl bis(2-ethylhexyl)phosphinate	EBEP
P, P,-dibutyl-N,N-diisopropylphosphinic amide	DIPA
disodium monomethylarsonate	DMA
chlorate-borate-monuron mixtures	CBMM[c]
chlorate-borate-fenuron mixtures	CBFM[c]
chlorate-borate-diuron mixtures	CBDM
chlorate-borate mixtures	CBM[c]
borate-monuron mixtures	BMM[c]
borate-2,4-D mixtures	BDM[c]
ammonium sulfamate	AMS
2-chloro-4,6-bis(ethylamino)-*s*-triazine	simazin[a] (sĭm′ ă zĭn)
2,3-dichloro-4-naphthoquinone	dichlone (dī′ klōn)
sodium methyldithiocarbamate	SMDC
3,5-dimethyltetrahydro-1,3-5,2H thiadiazine-2-thione	DMTT

[a]Common names "tentatively accepted" by the Terminology Committee of WSA.

[b]These herbicides are usually available for use as mixed isomers. When possible the isomers should be identified, the amount of each isomer in the mixture specified, and the source of the experimental chemicals given.

[c]These abbreviations are used to designate mixtures used as soil sterilants. The writer should indicate in a footnote the percentage composition of the product. For example: sodium chlorate—40.0%, sodium metaborate—57.0%, and monuron 1.0%.

C. *Abbreviations of terms used in weed control.*

The use of the following abbreviations is recommended and unless otherwise indicated, should be lower case letters without spacing or periods.

Abbreviations	Definitions
A	acre
ahg	acid equivalent per 100 gallons
bu	bushel or bushels
cfs	cubic feet per second
diam	diameter
fpm	feet per minute
ft	foot or feet
gal	gallon or gallons
gal/A, bu/A, oz/A, lb/A	gallon(s), bushel(s), ounce(s), pound(s) per acre
gpa	gallons per acre
gph	gallons per hour
gpm	gallons per minute
ht	height
ihg	active ingredient per 100 gallons
in	inch or inches
L	liter or liters
lb	pound or pounds
mi	mile or miles
ml	milliliter or milliliters
mm	millimeter or millimeters
mp	melting point
mph	miles per hour
oz	ounce or ounces
ppmv	parts per million by volume
ppmw	parts per million by weight
psi	pounds per square inch
ppt	precipitate or precipitation
pt	pint or pints
qt	quart or quarts
rpm	revolutions per minute
sp gr	specific gravity
sq	square
tech	technical
temp	temperature
wt	weight
WSA	Weed Society of America
SWC	Southern Weed Conference
NEWCC	Northeastern Weed Control Conference
NCWCC	North Central Weed Control Conference
WWCC	Western Weed Control Conference

Basal treatment. A woody plant treatment applied to the stems of plants at and just above the ground line.

Bed. (1) A narrow flat-topped ridge on which crops are grown with a furrow on each side for drainage of excess water. (2) An area in which seedlings or sprouts are grown before transplanting.

Bed-up. To build up beds or ridges with a tillage implement.

Biennial. A plant that completes its life cycle in two years. The first year it produces leaves and stores food. The second year it produces fruits and seeds.

Broadcast application. An application of spray or dust over an entire area rather than in a band only on rows, beds, or middles.

Blind cultivation. Cultivating before a planted crop emerges.

Brush control. Control of woody plants.

Carrier. The liquid or solid material added to a chemical or formulation to facilitate its field use.

Compatible. Two compounds are said to be compatible when they can be mixed without affecting each other's properties.

Concentration. Refers to amount of active material in a given volume of diluent. Recommendations and specifications for concentration of herbicides should be on the basis of pounds per unit volume of diluent.

Contact herbicide. A herbicide that kills primarily by contact with plant tissue rather than as a result of translocation.

Defoliator or *Defoliant.* A compound which causes the leaves, or foliage, to drop from the plant.

Diluent. Any liquid or solid material serving to dilute an active ingredient in the preparation of a formulation.

Directed Application. An application of spray or dust to a restricted area such as a row, or bed at base of plants.

Duckfoot cultivator. A field cultivator equipped with small sweep shovels.

Emulsifying agent. A surface active material which facilitates the suspension of one liquid in another.

Emulsion. The suspension of one liquid as minute globules in another liquid; for example, oil dispersed in water.

Epinasty. The twisting or curling of leaves and stems caused by a differential rate of growth of cells. (A state of growing in leaves in which the upper surface grows faster than the lower surface and thus causes the leaf edges to curve down.)

Growth stages of cereal crops. (1) Tillering stage—when a plant produces additional shoots from a single crown. (2) Jointing stage—when the internodes of the stem are elongating. (3) Boot stage—when the seed head of a plant begins to swell and emerge from the sheath.

Herbaceous. A plant that does not develop woody tissue.

Herbicide. A phytotoxic chemical used for killing or inhibiting the growth of plants.

Miscible. Two or more liquids which, when mixed together, form a uniform mix.

Perennial. A plant that lives for more than two years.

Noxious weed. A weed arbitrarily defined by law as being especially undesirable, troublesome, and difficult to control. Definition of the term "noxious weed" will vary according to legal interpretations.

Phytotoxic. A substance toxic to plants.

Post-emergence Treatment. Any treatment made after the crop plants emerge.

Pre-emergence Treatment. Any treatment made after a crop is planted but before it emerges. (1) *Contact pre-emergence.* An application made after weed emergence. (2) *Residual pre-emergence.* An application which kills weeds as the seed ger-

minates or as they emerge either before or after the crop has emerged.

Pre-planting treatment. Any treatment made before the crop is planted.

Rate and Dosage. These terms are synonymous. "Rate" is the preferred term. Rate usually refers to the amount of active ingredient material (such as 2,4–D acid equivalent) applied to a unit area (such as one acre) regardless of percentage of chemical in the carrier.

Selective Herbicide. A compound that is more toxic to one plant than to another.

Soil Sterilant. A herbicide that prevents the growth of plants when applied to the soil. Soil sterilization effects may be temporary or relatively permanent.

Spray Drift. The movement of airborne spray particles from the intended contact area to adjacent areas.

Surfactant. A material which facilitates, and accentuates the emulsifying, dispersing, spreading, wetting, and other surface-modifying properties of herbicide formulations.

Suspension. A system consisting of very finely divided solid particles dispersed in a solid, liquid or gas.

Synergism. Cooperative action of different agencies such that the total effect is greater than the sum of the two effects working independently.

Systemic Herbicide. A phytotoxic compound which is translocated within the plant.

Vapor Drift. The movement of herbicidal vapors from the area of application to adjacent areas.

Volatile. A compound is said to be volatile when it evaporates, or vaporizes (changes from a liquid to a gas) at ordinary temperatures on exposure to the air.

Wetting Agent. A compound which when added to a spray mixture causes it to contact plant surfaces more thoroughly.

Weed. A plant growing where it is not desired.

Crop. A plant growing where it is desired.

Weed eradication. The complete elimination of all live plants, plant parts, and seeds of a weed infestation from an area.

Weed control. The process of inhibiting weed growth and limiting weed infestations so that crops can be grown profitably or other operations can be conducted efficiently.

Prepared by the Terminology Committee, May 1, 1957

W. W. Allen
R. Behrens
L. G. Holm
C. I. Seely
W. C. Shaw, Chairman

News and Notes

The 4th Annual Convention of the Hawaii Weed Conference was held in Honolulu May 27 and 28, 1957. It was attended by personnel interested in weed control from the sugar and pineapple plantations, ranches, utilities, industry, the Armed Services, the Board of Agriculture and Forestry, the Hawaii Agricultural Experiment Station and Extension Service, Pineapple Research Institute and Hawaiian Sugar Planters' Association.

D. L. Linscott joined the Crops Protection Research Branch, ARS, USDA in June 1957 and will be stationed at Lincoln, Nebraska. He will be concerned with weed control research in pastures.

T. N. Johnson, Agronomist, Crops Protection Research Branch, ARS, USDA, returned to Flagstaff, Arizona after a temporary change in headquarters to Duke University. He will be responsible for the research on juniper control at Flagstaff.

After receiving his Ph.D. degree from Iowa State College, Robert Schieferstein accepted a position with the Chipman Chemical Company and will be stationed at Palo Alto, California.

The date of the Northeastern Weed Control Conference has been changed slightly. It will now be held January 8, 9, and 10, 1958 at the Hotel New Yorker, New York City. This is the Twelfth Annual Meeting of the Conference.

Melvin Sutherland has accepted a position, in which he will be screening chemicals for herbicidal activity, with the American Chemical Paint Company, Ambler, Pennsylvania. He was formerly an instructor in the Chemistry Department, Oregon State College, Corvallis, Oregon.

The Second Meeting of the Weed Society of America will be held January 13, 14, and 15, 1958, at the Peabody Hotel, Memphis, Tennessee. The Southern Weed Conference is acting as host for this meeting of the WSA.

Kuyoshi Kitasaki joined the research staff of the United States Borax & Chemical Corporation, Anaheim, California, on April 1, 1957. He was formerly herbicide synthesis chemist for Niagara Chemical Company, Middleport, New York.

Walter Gould joined the staff of the New Mexico Agricultural Exp. Sta. as Assistant in Agronomy in June, 1957, and will be concerned with the control of weeds. He received his M.S. degree from the University of Wyoming in the spring of 1957.

C. E. Fisher, Supt. of the Texas Agr. Exp. Station at Spur, Texas, has been transferred to Lubbock, Texas. Mr. Fisher initiated the mesquite control project at Spur in 1939 and has been a leader in the development of aerial control practices.

Tildon Easley will conduct cooperative research on weed control in pastures at the Mississippi Agr. Exp. Station, State College, Mississippi, as an employee of the Crops Protection Research Branch, ARS, USDA.

After receiving his Ph.D. degree from the University of Minnesota, Richard Yeo accepted a position with the Crops Protection Research Branch, ARS, USDA. He will work on methods of controlling aquatic weeds of irrigation in cooperative research with the Montana Agr. Expt. Station and will be stationed at Huntley, Montana.

Donald E. Seaman received his Ph.D. Degree from Purdue University in July 1957 and then joined the Crops Protection Research Branch, ARS, USDA. He will conduct cooperative work with the Florida Agric. Exp. Station on control of aquatic and ditchbank weeds and will be stationed at Fort Lauderdale, Florida.

Steve S. Szabo received his Ph.D. degree from the University of Wisconsin in October, 1957 and is now employed as an Assistant Agronomist by New Mexico College of Agriculture and Mechanic Arts. He will be concerned with various weed control problems.

Henry Wolfe, who was formerly Extension Weeds Specialist at the State College of Washington, has been promoted to County Agent Supervisor at the same institution.

The Ninth International Botanical Congress will be held in Montreal, Canada, from August 19 to 29, 1959, at McGill University and the University of Montreal. The program will include papers and symposia related to all branches of pure and applied botany. A first circular giving information on program, accommodation, excursions, and other detail will be available early in 1958. This circular and subsequent circulars including application forms will be sent only to those who write to the Secretary General, Dr. C. Frankton, IX International Botanical Congress, Science Service Building, Ottawa, Ontario, Canada.

"Weed Abstracts" is a non-profit making service which is prepared monthly from the world's literature on weeds, weed control and closely related subjects. In 1956 nearly 3,000 papers were abstracted or noted from the 400 journals and reports which are regularly searched.

"Weed Abstracts" is produced by the Agricultural Research Council Unit of Experimental Agronomy at Oxford and distributed by the British Weed Control Council, 58, Mark Lane, London, E. C. 3., England, on subscription at £ 2, 2s. 0d. per year.

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Spraying Systems Company, Bellwood, Illinois
Stauffer Chemical Company, New York, New York
Swift and Company (Plant Food Division), Chicago, Illinois
Thompson-Hayward Chemical Company, Kansas City, Missouri
United States Borax and Chemical Corp., Los Angeles, California

BIBLIOGRAPHY OF WEED INVESTIGATIONS
for
April, May, June, 1957

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Prepared By

UNITED STATES DEPARTMENT OF AGRICULTURE

Agricultural Research Service
Crops Research Division

This bibliography of current literature on weeds and their control is issued as a service to those engaged in weed research in the United States and other countries. In issuing this bibliography the Crops Research Division, Agricultural Research Service, U.S.D.A. does not assume responsibility for the subject matter cited.

Beltsville, Maryland

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IX. LEGAL ASPECTS

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